OPERATION ANALYSIS

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PREFACE

The importance of increasing the productivity of labor in industry as a means of enabling a greater number of people to share in an ever-increasing material prosperity has recently received recognition from industry and the general public alike. Society as a whole can share only what it produces, and however much the machinery for sharing may leave to be desired, the importance of increasing the productivity of our producing units cannot be overlooked.

The layman quite commonly associates increasing the productivity of labor with the invention and use of new or improved machines or the discovery of new processes of manufacture. New machines and processes are important in this connection, of course, and have been since the beginning of industrial history.

In many cases, new machines or processes are not available, or if they are, the money to purchase and install them may not be at hand. The idea of seeking to increase productivity need not be dropped in such cases, however. It has been demonstrated repeatedly that existing methods and processes can be improved if subjected to searching and systematic analysis, and the results that are obtained in the way of production increases are often equal to or greater than those which would result from the installation of new machinery.

It is the purpose of this book to describe the procedure for conducting operation analyses. Its application is inexpensive in comparison with the purchase of new equipment and once started it usually pays for itself many times over in the form of direct money savings. The application of the procedure is not limited to trained technicians, but it may be applied successfully by any industrial supervisor who wishes to bring about improvements in operating methods.

The book, therefore, will be of interest to all progressive men connected with the producing activities of any industrial enterprise, as well as to the serious student of the methods engineering procedure. The principles set forth are simple common-sense

principles which are readily understandable to the practical shop man. In all cases, the application of these principles is illustrated by numerous case examples drawn from many types of industry.

The procedure itself was developed by the authors to remove the process of operation analysis from the indefinite status of "something which should precede every motion and time study" and to make of it instead a specific, systematic procedure which would give results in the form of methods improvements. In so doing, the operation analysis procedure was developed into a tool which can be used by foremen, tool designers, inspectors, and other shop supervisors as well as by the methods engineer.

The authors wish here to express their appreciation to those industrial organizations who so freely cooperated in furnishing illustrative material for the case examples given throughout the book, particularly the Westinghouse Electric and Manufacturing Company, The Murray Corporation of America, The Pennwood Company, and The Mine Safety Appliances Company. Appreciation is also expressed to Mr. Howard Campbell, editor, for permission to reprint material published by one of the authors in the magazine *Modern Machine Shop*, particularly in connection with Chaps. IV and V, which first appeared in the July and August, 1936, issues of that magazine. Acknowledgment is also made to the staff of the Methods Engineering Council for its aid in preparing charts and drawings and for assisting in the task of proofreading.

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CHAPTER I

THE FUNCTION OF METHODS ENGINEERING IN INDUSTRY

Methods engineering is an essential part of scientific management; and because it offers a logical and systematic procedure for reducing costs, increasing production, and improving quality, it is a most valuable and widely used technique for solving management problems. Based as it is upon certain fundamental principles and laws, methods engineering may be applied with equal success to repetitive work or to jobbing work, to simple, easily understood operations or to complex, specialized jobs. Its principles are applied throughout the manufacturing industries and have also found applications in such fields as merchandising, transportation, and other enterprises where human labor is required.

Definition of Methods Engineering.—Before discussing the methods-engineering procedure in detail, it will be advisable to formulate a clear statement of what the term covers. Briefly it may be said that methods engineering is the industrial science which is chiefly concerned with increasing labor effectiveness. This definition, however, is likely to leave misconceptions in the minds of those who are not fully acquainted with the procedure, for they are likely to confuse labor effectiveness with labor effort and to believe that the procedure is designed to get more out of the worker by making him work harder. Since this is by no means the case, the following longer and more complete definition will be desirable.

> Methods engineering is the technique that subjects each operation of a given piece of work to close analysis in order to eliminate every unnecessary operation and in order to approach the quickest and best method of performing each

necessary operation; it includes the standardization of equipment, methods, and working conditions; it trains the operator to follow the standard method; when all this has been done, and not before, it determines by accurate measurement the number of standard hours in which an operator working with standard performance can do the job; finally, it usually, although not necessarily, devises a plan for compensating labor that encourages the operator to attain or to surpass standard performance.

It will be seen from this description that methods engineering includes more than the mere timing of operations. A diagram will permit a clearer visualization of this fact. Figure 1 shows graphically the elements of methods engineering and also certain of the devices and forms which are commonly used.

A methods study always begins with a careful primary analysis of existing conditions. The first factors that are considered are the number of pieces made or the yearly activity, the length of the operation, and the hourly rate of the operator or operators doing the job. This information permits the computation of the yearly cost of the job. An estimate is next made of the probable improvement that methods study can make. This in turn determines the kind and amount of methods-engineering work that can profitably be undertaken.

On the assumption that a fairly detailed study is indicated, one or more types of process charts are drawn up for the purpose of presenting the study problem clearly. Then complete information is compiled for each operation concerning such points as the purpose of the operation, inspection requirements, material and material handling, and tools and equipment used. Not infrequently this part of the study requires more time and accomplishes greater results than the succeeding steps, particularly when the analysis is made by a trained methods engineer of work that has not received much previous consideration.

When all known facts relating to the process, job, or operation have been ascertained, a secondary analysis, usually called "motion study," is made, assuming always that the time required to make it is justified by the results that are expected. At this point, each individual motion used in doing the work is considered in detail, not with the idea of attempting to get the worker to

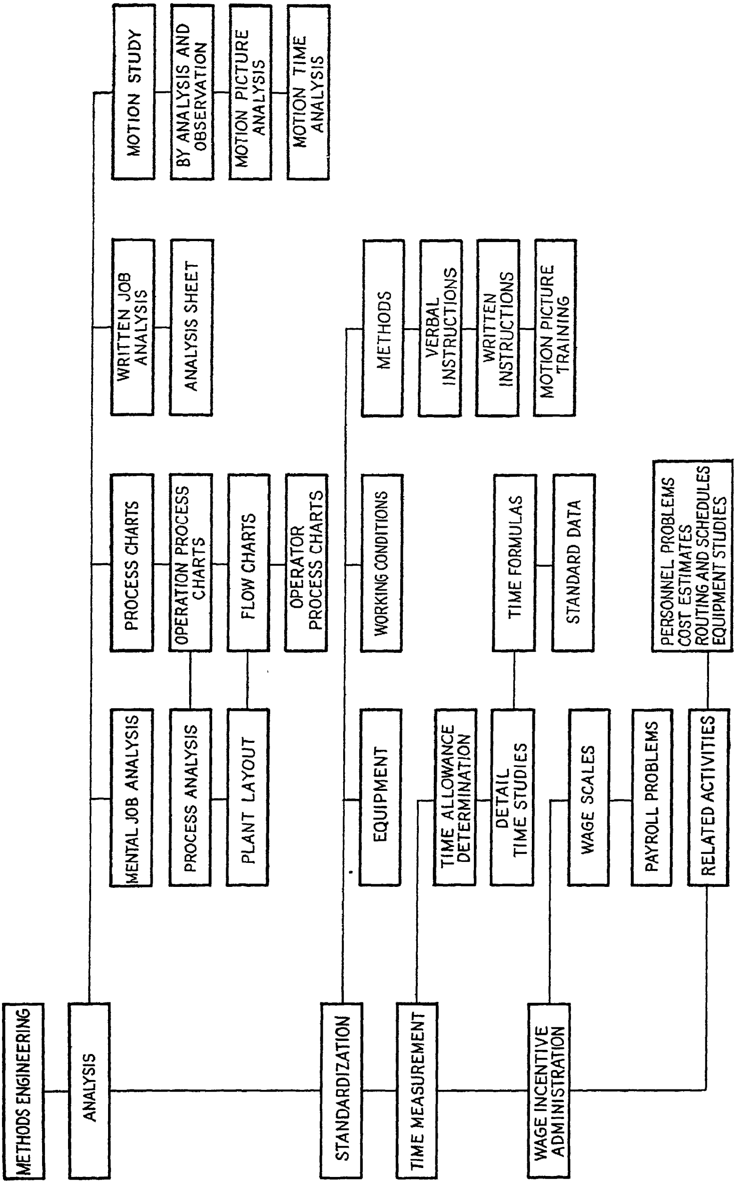


Fig. 1.—Graphic representation of elements of methods engineering.

make it faster, but rather to try to shorten the motion or to eliminate it altogether. Motion study leads directly to methods improvement, and the improvement is obtained by devising an easier and less fatiguing way of doing the job.

After the new method has been devised, equipment and conditions must be standardized so that the method can always be followed. Information and records describing the standard procedure must be carefully made and preserved; for experience has shown that, unless this is done, minor variations usually creep in and in time cause a major problem.

The operator or operators must next be taught to follow the new method. This may be done by verbal instructions, demonstrations at or away from the workplace, instruction sheets or operator process charts, or by the highly successful procedure that employs motion pictures.

Operator training is always important if a reasonable production is to be obtained, but it is an absolute necessity where methods have been devised by motion study. The best way of making each motion for each bodily part employed is carefully worked out by means of analysis and observation or motion-picture analysis, and a method that eliminates all useless or unprofitable motions is devised. This requires a few hours to several days of concentrated study. It is quite apparent, therefore, that the operators cannot be expected to discover for themselves the method which the engineer works out in this way, since they have neither the time nor the specialized knowledge necessary. They must, therefore, be carefully trained if they are to be expected to reach maximum production. Since time values are established on the basis of following the best methods, if the operators do not know and use them, they will fail to meet the allowances and will soon become dissatisfied and discouraged.

When the new and improved method has been devised and put into effect, the time required to do the work is carefully measured, usually by stop-watch time study. This measurement takes into consideration the skill and effort of the operator, and the final time allowance is based upon the standard performance that is expected from an operator who has been working at the class of work long enough to know it thoroughly, who is not unfitted for the work by nature, and who possesses normal intelligence and enough education to perform satisfactorily the work at

hand. The final time value that is established includes allowances for time lost due to fatigue and personal and unavoidable delays.

When the method is applied to an entire line of similar but varied work, time values are usually computed from time formulas. Time formulas are useful mathematical devices that the methods engineer employs to reduce the amount of time required to establish time values. They permit the establishing of a time value in 1 to 15 minutes that would require 1 to 100 or more hours to establish by detailed time study. Accuracy is in no way impaired but, as a matter of fact, is usually increased by the use of time formulas.

When the best method that can be worked out at the time is devised, the operators trained, and a correct time allowance established, a procedure is next devised which will insure that the method is followed and that standard production is attained. This procedure usually takes the form of an incentive plan, although it may call only for close supervision.

Theoretically, methods engineering ends here. In the past, the methods engineer attempted to separate himself from all matters connected with operator earnings, feeling that if he were responsible only for methods and time values his relations with the working force would be better. Actually, however, it is not possible to maintain this separation. Methods engineering and incentive plans are so closely related that the methods engineer is frequently consulted on wage scales, pay-roll problems, and matters of wage policy.

In addition, because of the training work that the introduction of new and often radically changed methods requires, methods engineering is involved with personnel problems. In large plants where personnel work and methods work are two distinct activities, the personnel man and the methods man find it necessary to work together closely. The interrelation of certain phases of their activities is so natural that in smaller plants one finds the two functions combined in the duties of a single individual. The methods man then includes employment, wage-rate determination, and so on, with his other duties; and since in plants where this has been done the setup has functioned satisfactorily, it would seem to indicate that a competent methods man using the modern, scientific methods-engineering procedure need not

hesitate to assume full responsibility for all phases of wage administration.

Explanation of the Term "Methods Engineering."—The term "methods engineering" is of comparatively recent origin. It is used not only because, when analyzed, it is fairly descriptive of the work done by those engineers who are charged with the responsibility of increasing labor effectiveness, but also because it is desired to separate present-day conceptions from those of the past. Methods engineering is not job analysis or motion study or time study, but it is a combination of these and other techniques welded together to form one practical and universally applicable whole.

Methods work, in common with all promising procedures undergoing development, has suffered much in the past at the hands of self-styled experts who in reality had little or no knowledge of the work. Indeed, during and immediately after the World War, many efficiency experts mushroomed into existence and by their inexpert attempts to handle a delicate tool without understanding it did so much real harm that methods work suffered many setbacks. Hence, the term "efficiency engineer" is now practically obsolete and is commonly avoided throughout the industrial world. The place of the untrained "experts" has been taken by the capable, trained methods engineer who brings to his job an extensive knowledge of fundamental waste-eliminating practices.

Development of Methods Engineering.—The development of modern methods engineering required a number of years and, as is the case with all new developments, progressed slowly with frequent false starts and retrogressions. Its history is interesting and is worthy of a brief description.

Probably the oldest wage-payment plan to be used by man was not daywork, as might be supposed, but piecework. In going back to primitive times, the imagination must be largely relied upon, but it seems reasonable to assume that the hunter, for example, contracted with the arrow maker on a piecework basis. When he brought in a deer, he would offer it in exchange for, say five arrows. This was nothing more or less than piecework. The arrow had a definite piece rate equal to one-fifth of a deer. The value of the arrow was probably determined from a vague conception of the average time required to produce an

arrow in comparison with the average time required to kill a deer. It is doubtful if this thought was ever expressed in so many words, but it is likely that it formed the basis for determining the rate of exchange.

Once the rate was established, the time spent by the arrow maker in making an arrow and the time spent by the hunter in bringing in a deer were not considered by the contracting parties. If the arrow maker, for example, were industrious and skilled, he produced a number of arrows during the day and thus was able to receive a considerable amount of other material products in return. If he were lazy or unskilled, he would turn out only a few arrows and in consequence had to be satisfied with a bare living.

Daywork probably came into being only when one man desired to pay another man to work for him at a variety of tasks or to retain his general services to use or not at his discretion. Servants, for example, were paid on this basis. As industry began to grow, daywork was used more and more, probably because this was the easiest method of payment where a variety of work was handled. Supervision was direct in most cases, labor was plentiful, and fear of dismissal furnished the incentive to produce.

At the same time, piecework payment was used in a number of instances. The weaver who worked a loom in his own home was paid for what he produced and not for the number of hours he spent at work.

As industrial units became larger, the work became more complex, and it was commonly felt that all work except simple, highly repetitive jobs had to be done on a daywork basis. As the work became more complex, however, supervision became more difficult, and the need for piecework or some plan that encouraged a definite output by the workers was felt more keenly. It was only natural therefore that this situation resulted in attempts to introduce incentives.

The first attempts at incentive installations were altogether different from the present-day practices. Piecework, because it was simple, was the commonly used plan, and the duty of establishing piece rates was given to the foreman as a sort of extra duty. The foreman soon found himself with an unsatisfactory condition on his hands. In the first place, he usually had many duties of a pressing nature claiming his attention, and he had

little or no time to devote to careful rate setting. In the second place, even when he found time to give to the setting of a rate, he had no accurate way of doing it. No instructions as to proper rate-setting procedure were given him because none had been developed. He was expected to base his rates upon records of past performance and his own judgment of what a man could accomplish if he worked with an honest effort.

These two factors proved to be utterly unreliable. Records of past performance told only how much was produced and gave no indication of the conditions under which the work was done or of the method used by the operator. Under the stimulus of an incentive, the operator could almost always devise a better method and, by working steadily with a good effort, could make earnings that often exceeded those of the foreman.

As soon as the foreman realized that past records were at best only a guide, he attempted to judge from his general knowledge of the work what degree of improvement could be expected. This, of course, was a step in the right direction, but it did not go far enough. On some jobs, the method used could not be much improved; and hence the rate that allowed for improvement was too low, and the worker's earnings suffered. Again, an improvement beyond that which the foreman anticipated made high earnings possible and increased the dissatisfaction of the worker with the low-rated job.

On the one hand, the foreman was assailed by the worker to raise the low rates. On the other, he was called "on the carpet" by his employer because certain rates, and hence earnings, were too high. In these circumstances, the foreman did the only thing he could do. He raised the low rates where he had to and cut the high rates wherever earnings were excessive.

The result was what might be expected. The raising of the low rates was regarded by the worker as a proper correction of an error of judgment, whereas the lowering of the high rates was regarded as an indication that a man was to be permitted to earn only so much and that there was no use trying to earn more. This, of course, defeated the purpose of incentives which was to stimulate production. When this was pointed out to the harassed foreman by the employer, he could only say that he was doing the best he could under the circumstances and that he would try to find time to do a more careful job in the future.

All this time, competition was becoming increasingly keen. The need for incentives was felt most strongly, and the importance of proper rate setting caused a search for a better way of handling the matter. It was reasoned that, although the foreman knew more about the work than anyone else, he had little time to devote to rate setting. The solution to the problem therefore appeared to lie in selecting another man who knew nearly as much about the work and giving him the task of rate setting as a full-time job. Thus the position of rate setter was established.

The new setup gave somewhat better results, but conditions were far from satisfactory. The rate setter relied on records and judgment for establishing rates just as the foreman had done. Records of past performance, however, were no more reliable than they had ever been; and although the judgment exercised was somewhat more mature owing to the greater amount of time spent on considering the job, the results that were obtained were not appreciably better from the worker's standpoint.

Toward the end of the nineteenth century, therefore, the more progressive plants began to feel the need for a better, fairer, and more accurate method of handling the rate question. The problem was attacked independently in a number of plants in this country and abroad, and various solutions were offered which have contributed to a greater or lesser extent to methods-engineering practices. One attack, for example, was to attempt to equalize the inconsistencies of poor rate setting by the wage-payment plan; and this led to the development of such well-known plans as the Halsey premium plan and, later, the Rowan plan.

It was not until Dr. Frederick W. Taylor began to experiment with what he called "time study," however, that real progress was made. A great deal has been written eulogizing the work of Taylor. He is entirely deserving of it all. In evaluating the extent of his accomplishments, the conditions under which he introduced his methods into industry must be considered. Everything about industry was unsystematized. There were no staff activities such as personnel departments, employment departments, and so on. The line supervisors did their own hiring and firing and, in many cases, their own purchasing. They established methods based upon long experience, or if not,

they usually had the authority to accept, reject, or change those established by a rate setter. Usually the supervisors had come up from the ranks, had themselves done all of the work that they supervised, and felt as a natural result that no one could tell them anything they did not know.

This was the type of man Taylor had to deal with on the supervisory end. It was a vastly different type from the present-day open-minded, intelligent superintendent or foreman. The workers were no easier to approach. They had suffered for years from various attempts at rate setting, and they had no reason to feel that Taylor would treat them any better than anyone else. They objected to the stop watch and disliked having their every move recorded and timed. Taylor while making studies was often asked by the men with a certain crude humor, "How much time is allowed for spitting?", "What am I supposed to do when the boss wants to talk to me?", and many other similar questions. It required courage, persistence, and faith in the rightness of his work to go ahead in the face of this opposition.

The results shown by the first time studies did not tend to induce ready acceptance of the new technique. Taylor found that the men he studied were not of constant effectiveness but gave performances that were good, bad, and indifferent. Some were following improper methods, many did not take full advantage of their tools and equipment, and all were subject to many interruptions. Hence, Taylor often found that a man could do two or three times as much as he had previously done in a day.

It is not difficult to visualize how an announcement to this effect might be received. The best performance on a certain job was previously 10 pieces a day. Taylor said, after study, that 30 should be produced. The operator on whom the study was taken was considered an expert. Taylor was a white-collar man, considered to have little or no knowledge of the work. Small wonder, then, that he was laughed at at first. He persevered, however, and by patiently showing what must be done was able to secure the production increases he predicted. Eventually his procedure was accepted where he and his associates worked personally, and it attracted a great deal of attention elsewhere.

Since those days, time study has increased the productivity of industry manyfold. It has resulted in improved conditions, standardization, reduced costs, better production control, and

better satisfied labor wherever it has been properly applied, and it has been applied to nearly every class of work.

Taylor's system was to give the workman a definite task to be accomplished in a definite time in a definite manner. The workman was told in detail how to do the job. The method was established by careful study.

Taylor's original procedure forms the basis of methods engineering. It has been improved upon by those who came after him, as is the case when any new science is developed. The most remarkable part of his work, however, is that surrounded by chaotic, hit-or-miss procedures, he originated, described, or predicted practically all the developments that have since taken place. This perhaps is the greatest tribute to the ability, clear thinking, and foresight of Taylor that can be made.

Taylor never failed to stress the importance of the method used for doing the job, but his stop-watch time-study procedure was so striking that many who attempted to use his system overlooked the importance of careful methods study. They became so engrossed with the details of accurately measuring the time for doing the job that they often timed the job as it was then being done without questioning the method. When improvements were made, they were the result of inspiration rather than of systematic analysis.

It was Frank B. Gilbreth who did more than anyone else during the early development stage of methods engineering to stress the importance of the detailed study of methods. As an apprentice bricklayer, he became impressed with the fact that most bricklayers had their own way of doing a job. Being very observant, he noticed further that each worker had three ways of doing the same job: one that he taught to other inexperienced workers, one that he used when working slowly, and one that he used when working at his normal speed. Gilbreth became interested in the reasons underlying this and aided by his wife, Dr. Lillian Gilbreth, he devoted the rest of his life to developing the technique of motion study.

The Gilbreths established a laboratory and studied motions by laboratory methods. As a result, they made a number of fundamental discoveries and originated the concept of therbligs, or basic divisions of accomplishment. They were the first to recognize that there are certain definite principles which govern

efficient working practices, and they developed several techniques for studying the motions used in performing operations. Of these, the motion study made with the aid of motion pictures, often called the "micromotion technique," is the best known and most used.

The Gilbreths did a piece of pioneering work that was comparable to Taylor's. Their developments, however, were at first not generally accepted by so-called practical men because of the laboratory aspects of their work. Acceptance was further retarded by the attempts of enthusiastic followers to discredit stop-watch time study and to advance motion study as the only answer to all management problems connected with methods study and rate setting. This aroused the antagonism of those who were successfully using the time-study technique and estranged a group who might otherwise have been the first to benefit from the developments of the Gilbreths. Of the originality, soundness, and value of their contribution to methods engineering, however, there can be no question.

As has been pointed out, Taylor's original work forms the basis of modern methods engineering. Although the developments made by the Gilbreths are probably the most widely known, a number of other engineers have contributed important principles and practices that have advanced methods engineering at least part of the way from the status of an art to that of a science.

Nearly all the laws and principles first advanced have been developed, restated, and clarified. Analysis has been removed from a general something that the methods engineer should carry out to a carefully planned, systematic procedure. Process charts have been developed to a state of greater flexibility and have become more useful for general analysis purposes. Better designs of industrial motion-picture equipment permit the wider use of the motion picture at a greatly reduced cost. The element of time has been tied in with the concept of therbligs, or basic divisions of accomplishment, thus offering a new and valuable approach to methods study. The leveling principle permits adjusting the time data obtained from a study taken on any kind of performance over a wide range to a standard level with a high degree of accuracy, thus permitting the setting of accurate and consistent rates. Finally, time-formula derivation has been

developed to a point that makes possible the quick and accurate setting of a large number of rates or time allowances with a minimum of engineering effort.

In spite of the progress that has thus far been made, the methods-engineering procedure, at the present time, is constantly being revised and improved, as is any profession or procedure that is in everyday use. It is entirely probable that as new ideas are advanced and new developments made the present technique will be still further improved upon in the future. The technique is, however, capable of being applied to all kinds of work, and its application results in major improvements in operating methods.

Economic Function of Methods Engineering.—Under modern business conditions, one of the major problems which faces the managers of industry is that of constantly reducing costs. Owing to national and world economic conditions, markets are restricted, not because there is no demand for the goods that are produced, but because many individuals are economically unable to satisfy any but a small fraction of their demands. Even in periods of prosperity, millions of people are able to supply themselves with only the barest necessities of life.

The population of this or any other country may be regarded as being made up of a number of groups having approximately the same income range. There are the fewest individuals in the highest group and, at the present at least, the greatest number in the lowest group. This may be represented as in Fig. 2, with the lowest economic group at the bottom and the other groups on top in order of increasing income. At each level, there is a group with a certain purchasing power; and although in good times a few more are in the higher levels than in times of depression, still the variation is not great in proportion to the total population.

The result then is a relatively constant market for any given class of goods. This would not be serious if any one industry could forget all its other problems and could gear its production to its market. The fluctuations caused by good and bad times spread over all the members of the industry would not be large and could be handled without difficulty by advanced planning.

The trouble is that no industry can concentrate solely upon adjusting its production to the purchasing power of its market. One factor alone in the present-day situation would prevent that. If any industry arranged its affairs so that all members were con-

sistently making money, there would at once be an influx of new units into that industry. If the members of the pencil industry, for example, were universally prosperous, it would not be long before manufacturing units that were not making money at the production of rolling pins, tacks, or wrenches would decide to

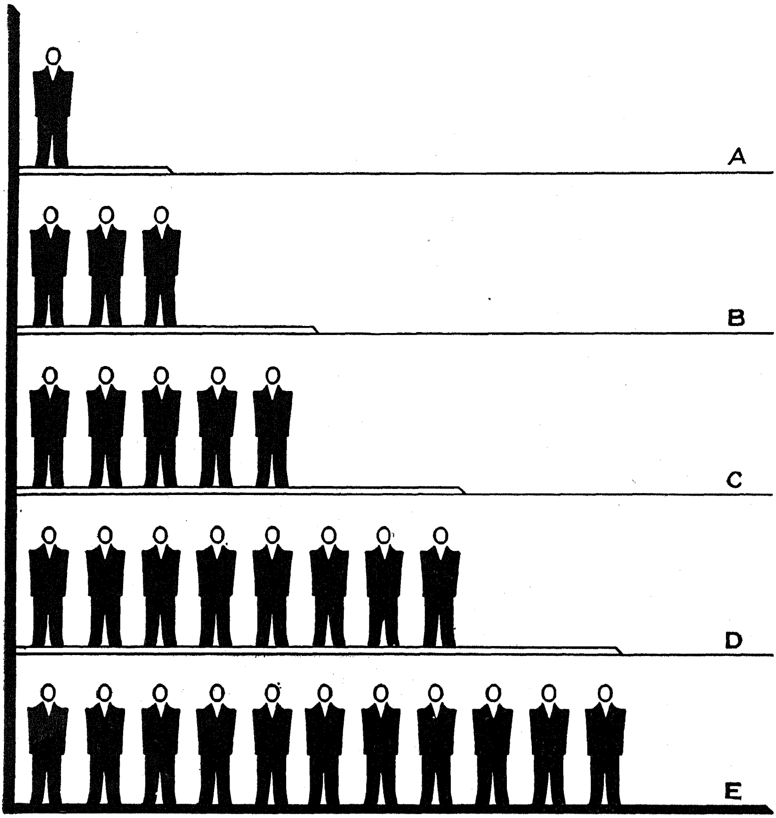


FIG. 2.—Economic strata of modern society.

equip for making pencils. Any influx of new units has a highly disturbing effect on an industry, for the new units are certain to get at least a share of the business, thus leaving less for the old units. Further, because they are new, they bring with them a vast amount of inexperience which will cause them to produce poor products, sell below the cost of manufacture, and make other

blunders which, although suicidal in the long run, increase the difficulties of the better-managed plants while the former are in business.

Not only is competition found within the industry, but also industries compete among themselves. Fountain pens compete with indelible pencils, and typewriters with fountain pens. The buying public is notoriously fickle, and style changes or the introduction of a new substitute may completely wipe out a market

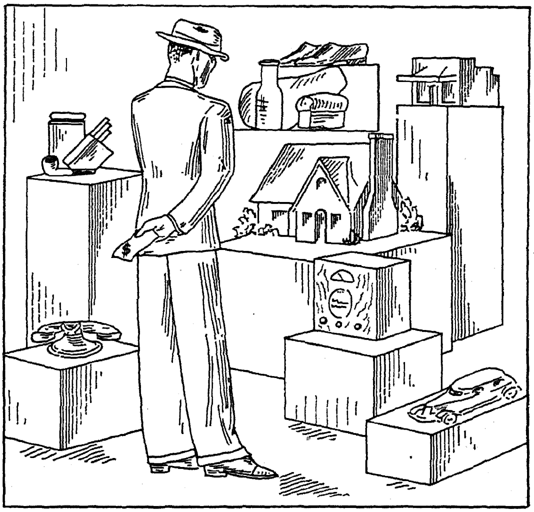


FIG. 3.—Competition among products for consumer's dollar is increasingly keen.

that appeared steady and lasting. What the style of bobbing hair did to the hairpin industry is obvious.

The consumers at any economic levels but the highest few have only a limited amount to spend. All kinds of products are offered to them in various enticing ways. Competition as a result is keen and ruthless. The only way an industrial unit can hope to survive under these conditions is constantly to seek to keep production costs as low as possible.

Not many years ago, when cost reductions were necessary for one reason or another, they were obtained by reducing wages. The possibilities of obtaining cost reductions by increasing the production of the workers were not at the time generally recognized. Recently, however, there has been a marked change.

The employer has come to realize that the worker is also a consumer and that, if wages are reduced, purchasing power is reduced. Therefore, a better way toward cost reduction lies in waste elimination so that greater production is secured with less effort.

Methods engineering is primarily concerned with devising methods that increase production and reduce costs. Hence, it plays an important role in determining the competitive position of a plant. As competition appears to be becoming keener, it is probable that methods engineering will become increasingly important.

Methods engineering in an industrial unit can never be considered as completed. Costs that are satisfactory and competitive today become excessive in a comparatively short time because of the improved developments of other units of the industry. If the producer who is in a good competitive position today decides that his costs have reached rock bottom and that no further attempt to improve them is necessary, within a short while he is likely to find himself facing loss of his commercial standing as owner of an efficiently managed plant. Only by constantly seeking to improve can any unit safeguard its competitive position. Conditions in industry are never static, and steady progress is the only sure way to success.

Although cost-reduction work is important as a factor for survival, an even more important advantage accrues when really worth-while savings are effected. Figure 2 illustrates the various economic strata of society. Assume that a certain company is manufacturing a product that, although universally desirable, is priced so high that only those individuals in group *C* or higher can purchase it. The market for the product is thus rather limited.

If, however, properly conducted cost-reduction work permits the lowering of the selling price so that the individuals in group *D* can purchase the product, the market is at once greatly expanded, perhaps doubled or even tripled. Henry Ford was among the first to combine recognition of this principle with the courage to act upon it.

In actual practice, society is not divided into definite groups, but incomes range, in small steps, from next to nothing to the highest. Hence, each time the selling price of a product is

reduced, even though it is as little as 1 per cent, the product is brought within the reach of more people. Therefore, it may be seen that cost reduction as a means of increasing the distribution of the product is at all times important.

Methods Engineering and Shop Supervisors.—The methods man is by no means the only one who takes an interest in establishing economic costs and improving methods. The foremen, the tool designers, and the other shop supervisors all realize the importance of keeping costs upon a competitive level. Very often they make worth-while improvements in manufacturing methods. The differences between the methods man and the other shop supervisors are two. In the first place, the methods man devotes all his time to methods work, whereas the other supervisors have numerous duties which force them to consider methods work as incidental to their major activities. In the second place, the methods man conducts his methods studies systematically and makes improvements as the result of applying a carefully developed technique. This technique is based upon a large amount of specialized knowledge which can be acquired only by special study and training. Therefore, unless a course in methods engineering has been given to the other shop supervisors, their improvements are less certain and are due more to inspiration than to deliberate intent.

For these reasons, the major part of methods improvement is usually made by methods engineers. This is not a necessary condition, however; for the principles that they use can be learned by the other supervisors and can be applied, in part at least, during the course of their other work. Certain progressive organizations have realized this and have given methods-engineering training in more or less detail to their various key supervisors. The results, as may be expected, have been gratifying, and methods-improvement work has received a marked impetus.

It is hoped that this book will be used by shop supervisors such as foremen, tool designers, and so on, as well as by methods engineers; for if the principles of methods work are understood throughout an organization, that organization will be in a good position to meet competition, depressions, or any other economic disturbances which may come its way.

CHAPTER II

APPROACH TO OPERATION ANALYSIS

The factors that surround even the simplest industrial operation are many and varied, and comparatively small progress toward improvement will be made if any job is studied as a whole. Therefore, the first step in the study of any job is to make a thorough analysis by resolving it into its component parts or elements. Each part or element may then be considered separately, and the study of the operation thus becomes a series of fairly simple problems.

During primary analysis, the operation is broken down into such general factors as material, inspection requirements, and working conditions. Each one of these factors is then examined minutely and critically in order to discover possibilities for improvement. This kind of analytical work is commonly understood to be covered by the term "operation analysis," and it will be discussed in considerable detail in the present volume. An operation analysis may be undertaken by anyone who understands the principles of this technique and, when systematically conducted, usually leads to improvements of various sorts.

It should be borne in mind that, although the first step of methods study consists of operation analysis, analytical work does not cease then but continues in more or less detail throughout the entire study. During secondary analysis or motion study, for example, attention is focused on a single element of the primary breakdown, namely, the method. The method is resolved into terms of basic divisions of accomplishment or basic operations, a process that is a highly refined type of analysis. Even during stop-watch time study, analysis continues, although it is not so detailed as the preceding kinds.

Approach to Operation Analysis.—To conduct analysis work successfully, a distinctive mental attitude must be developed. When one is in any way familiar with a subject, there is a natural tendency to take pride in this familiarity. There is a further

tendency to feel that a goal has been attained and that additional consideration is unnecessary. This attitude, commendable as it may be as a means of securing peace of mind in everyday affairs, is fatal to searching analysis. If it is felt that everything is known about a certain point and that it need not be considered further, then no improvement can possibly be made. In order to improve an operation, it must be approached with the idea that it can be improved. Otherwise, failure is almost certain to result.

If a job has previously been carefully studied, the best method may conceivably have been devised, and no further improvement may be possible. Experience has shown, however, that there are few established methods which cannot be improved if sufficient thought is given to them. In this connection, the history of a certain bench operation furnishes an excellent and by no means uncommon illustration of this point. The job originally was done on daywork, and past production records showed that the time taken per part was 0.0140 hour, or slightly less than 1 minute. The job was time-studied and put on an incentive basis with an allowance of 0.0082 hour. The operator worked with a good effort and made a fair bonus, and the feeling existed for some time that the proper method was being followed.

After the operation had been set up for 6 months, however, a suggestion for improvement was advanced. The suggestion was not based upon systematic analysis but rather was the result of inspiration. The suggestion was put into effect; and when the job was restudied, an allowance of 0.0062 hour was set. This last method was followed for 6 months more, when another suggestion, also of the inspirational type, was advanced. It was adopted, and a new time value of 0.0044 hour was established.

The job was a prominent one, and the changes attracted considerable attention. The thought was advanced that if improvement was possible in the past it might be possible in the future; hence, the job was selected for detailed motion study. The operation was carefully analyzed by a trained methods engineer, with the result that a completely new method was devised which followed the principles of correct motion practices. When the new method was time-studied, an allowance of 0.0013 hour was set.

The operation was thus improved to an extent where the time required was only approximately one-eleventh of that taken at

first on the old daywork basis or one-sixth of that taken when the original method was followed under incentive conditions. An improvement of such great magnitude justifies the statement that the latest method is a very good method; but in view of the past history of the job, it would be unwise to say that the best method has been attained.

As the result of many similar experiences, methods engineers are reluctant to speak without qualifying clauses about the "best" method. It is safer to speak of "the best method yet devised," implying recognition of the fact that further improvement may be possible even if from an economic standpoint it may not be practical at the time to seek it. Carrying this thought to a logical conclusion, the best method of doing an operation from a labor-economy standpoint is reached only when the labor required has been reduced to zero. Until this point has been reached, further improvement is always possible.

This principle furnishes a foundation for the approach to operation analysis. If it is clearly recognized, it insures an open mind. Such mental obstacles as "it won't work," "it can't be done," and "it was tried before and didn't work" are cleared away at the outset. Lack of success in improving any job is not interpreted to mean that the job cannot be improved, but rather that no way of improving it has yet been discovered. There is a vast difference in the two interpretations. The first induces contentment with things as they are and leads to stagnation; the second inspires further attacks from different angles and leads to progress.

The Questioning Attitude.—An open mind paves the way for successful analytical work, but it is not sufficient in itself. One can be open-minded in the passive sense of being receptive to suggestions, but this will not lead to accomplishment. The analyst must take the initiative in originating suggestions himself if he wishes to get results.

Other things being equal, the greatest amount of originality, or what passes for originality in a world where it is often said that there is nothing new, is evinced by those who have an inquiring turn of mind. The man who constantly asks questions and takes nothing for granted is often a disturbance to the contentment of those who are willing to accept things as they are, but he is the one who originates new things. Improvements come from first

examining what is with an open mind and then inquiring into what might be.

This point should be clearly understood, and what is known as the "questioning attitude" should conscientiously be developed. In making an investigation of a job, nothing should be taken for granted, and everything should be questioned. Then the answers should be determined on the basis of facts, and the influence of emotions, likes and dislikes, or preconceived prejudices should be guarded against.

One who is successful in bringing about improvements in operating methods has few deep-seated convictions. He accepts little or nothing as being right because it exists. Instead, he asks questions and gathers answers which he evaluates in the light of his knowledge and experience. He questions methods, tools, and layouts. He investigates all phases of every job he studies, in so far, at least, as he has time. He even asks questions when the answers appear obvious, if he thinks he can bring out something by so doing.

The questions asked take the general form of "what," "why," "how," "who," "where," and "when." What is the operation? Why is it performed? How is it done? Who does it? Where is it done? When is it done in relation to other operations? These questions, in one form or another, should be asked about every factor connected with the job being analyzed. Typical questions that arise during the study of industrial operations are as follows:

If more than one operator is working on the same job, are all operators using the same method? If not, why not? Is the operator comfortable? Sitting down as much as possible? Has the stool or chair being used a comfortable back and a seat that is wide enough? Is the lighting good? Is the temperature of the work station right? Are there no drafts? Are there armrests for the operator? If the operation can be done either seated or standing, is the height of the chair such that the elbows of the operator are the same distance from the floor in either case?

Can a fixture be used? Are the position and height of the fixture correct? Is the fixture the best available? Is the fixture designed in accordance with the principles of motion economy? Would a fixture holding more than one piece be better than one holding a single piece? Can the same fixture be used for more

than one operation? Can a clamp, a vise, or a fixture be substituted for the human hand for holding? Are semiautomatic tools such as ratchet or power-driven wrenches or screw drivers applicable?

Is the operator using both hands all the time? If so, are the operations symmetrical? Do the hands move simultaneously in opposite directions? Can two pieces be handled at one time to better advantage than one? Can a foot device be arranged so that an operation now performed by hand can be done by foot?

Are raw materials properly placed? Are there racks for pans of material and containers for smaller parts? Can the parts be secured without searching and selecting? Are the most frequently used parts placed in the most convenient location? Are the handling methods and equipment satisfactory? Would a roller or a belt conveyer facilitate handling? Can the parts be placed aside by means of a chute?

Is the design of the apparatus the best from the viewpoint of manufacturing economy? Can the design be changed to facilitate machining or assembly without affecting the quality of the apparatus? Are tools designed so as to insure minimum manipulation time? Can eccentric clamps or ejectors be used?

Is the job on the proper machine? Are the correct feeds and speeds being used? Are the specified tolerances correct for the use to which the part is to be put? Is the material the most economical for the job? Can the operator run more than one machine or perform another operation while the machine is making a cut? Would a bench of special design be better than a standard bench? Is the work area properly laid out?

This list of questions could be extended almost indefinitely, but enough have been given to illustrate the sort of questions that should be asked during a methods study. The importance of asking such questions is paramount. The chief difference between a successful analyst and one who seldom accomplishes much is that the former has developed the questioning attitude to a high degree. The latter may be capable of making the same improvements as the former, but they do not occur to him as possibilities because he accepts things as they are instead of questioning them.

Operation Analysis Need Not Be Confined to Methods Engineers.—Although the questioning attitude is developed by the

methods engineer as an aid to thorough analysis, it need not be and should not be solely his property. The other shop supervisors will find it equally useful for attacking their particular problems and finding solutions for them. If they focus it on operating methods, they will be able to make many improvements in the course of their daily work. Thus, methods-improvement work will progress more rapidly than it would if it were left entirely to the methods engineer.

If a plant is small and has insufficient activity to justify employing anyone in the capacity of methods engineer, it will be particularly desirable for all members of the supervisory force to develop the questioning attitude. It is extremely easy to view things without seeing them when they are supposedly familiar. Those most familiar with the work are the least likely to see opportunities for improvement, unless they consciously try to remain as aware of their surroundings as they would be were they new to the plant. Where the supervisory group does not change often, the cultivation of the questioning attitude is almost essential to progress.

Questions should not be asked at random, although this would be better than asking no questions at all. Rather, it is better to proceed systematically, questioning points in the order in which they should be acted upon. It would be unwise, for example, to question the tools, setup, and method used on a certain job before the purpose of the operation was considered. Better tools might be devised, and the method might be changed; but if it were later found upon examination of the purpose of the operation that it need not be done at all, the time and money spent on tool and methods changes would be wasted.

In the chapters that follow, the steps that should be followed in making a systematic job analysis will be discussed in sufficient detail to give a thorough understanding of them. The principles that are set forth are simple, and they may be put into effect as quickly as they are grasped.

Making Suggestions for Improvement.—When a job is examined in all its details with an open mind and when all factors that are related to it are questioned, possibilities for improvement are almost certain to be uncovered if the job has not been studied in this way before. The action that is taken upon the possibilities will depend upon the position of the one who uncovers

them. If he has the authority to take action and approve expenditures, he will undoubtedly go ahead and make the improvements without further preliminaries. If, however, he does not have that authority, he must present his ideas in the form of suggestions to the one who does.

There are certain pitfalls to be avoided in making suggestions. In the first place, the true worth of each suggestion should be carefully evaluated before it is offered. If he establishes a reputation for offering only suggestions of real merit, one will find it easier to secure an attentive hearing than if he is continually advancing suggestions that have to be examined to separate the good from the impractical.

The quickest way to prove the merit of any suggestion is to make or obtain estimates of the cost of adopting it and of the total yearly saving it may be expected to effect. These two figures will show just how much must be spent and how long it will be before the expenditure will be returned. If a suggestion costs $1,000 to adopt and will save $100 per year, it is not worth presenting unless there are unusual circumstances. If, on the other hand, the expenditure will be returned within a reasonable length of time, the suggestion is worthy of careful consideration.

When it has been definitely decided that the suggestion is sound and valuable, it should be presented to the proper authorities for approval. Here, again, estimates of expenditure and return will prove valuable. The statement that much time will be saved or even that a saving of 0.0050 hour per piece can be made is not likely to mean so much as figures showing a saving of a certain number of dollars per year. A complete presentation which includes cost and savings totals will be appreciated, for if they are not furnished, they must be requested anyway, and this will only postpone final action.

An example of a good presentation of a labor-saving idea is as follows:

Works Manager:

By analyzing the cork-tube winding operation in the Cork Department, it has been found that one-third of the winder's time is spent in doing work requiring a high degree of skill and the remaining two-thirds in doing work that could be satisfactorily performed by unskilled labor.

The time consumed by the portion of the cycle that requires high skill is almost exactly one-half of that required for the balance. Therefore, it will be entirely feasible to place four winding machines in a group, using one skilled man with two unskilled helpers to run them. In this manner, the average production of three skilled workers running three machines will be obtained at a greatly reduced cost.

Under the proposed setup, the skilled worker will apply the cork to the cloth core which has been set up by one helper and will then move to another machine which the other helper has set up. Each helper will tie the ends of a finished cork-covered tube, will remove the tube, and will set up another while the skilled man is busy at other machines.

The skilled man receives 60 cents per hour and the unskilled men 40 cents per hour each. The labor cost per tube will therefore be approximately 0.76 cent as compared with the present cost of 1 cent each.

On the basis of present activities, this will amount to a yearly saving of $2,361.55. There will be a certain amount of idle machine time under the proposed arrangement; but since we have more machine equipment than we require for our present volume of business, this need not be considered.

This matter has been discussed with the foreman, Mr. H. J. Jones, and he believes that the arrangement will work satisfactorily. In order to proceed with the proposed change, it will be necessary to relocate 12 machines. Mr. Bolland of the Maintenance Department estimates that this can be done for a cost of $480.

In view of the savings that can be made, Mr. Jones and I wish to request authorization for the above expenditure.

Signed ____________________

In this report, enough details are given to explain the general nature of the suggestion. The total yearly saving of $2,361.55 is shown, as also are the cost of adopting the suggestion and the source of the estimate. The fact that the suggestion meets with the approval of the foreman of the department, always a most important point, is also clearly stated. As a result, all questions that are likely to arise in the mind of the manager are answered in advance, and there is a good likelihood that he will give immediate approval.

Occasionally, ideas occur which appear to possess advantages to the originator other than those which can be measured in dollars and cents. In presenting suggestions of this nature,

advantages and disadvantages should be presented in tabulated form, so that a decision can be quickly made.

Ideas of this kind are more subject to rejection than those which show definite money savings. Perhaps the advantages to be gained are so largely theoretical that a busy man is not able to visualize them, or perhaps the cost of making the change seems to outweigh the intangible benefits that are expected. If a suggestion of this type is rejected after proper presentation, the suggester should drop it and cease to worry about it. Fretting about unadopted ideas occupies the mind when it should be engaged in originating new suggestions and often causes dissatisfaction and reduces efficiency.

The rejection of an idea does not mean that it possesses no merit. It merely indicates that the benefits it offered did not appear to the one who made the decision to be sufficiently important to warrant expending the effort necessary to get them. The decision is made in the light of such factors as present trends, the future business outlook, and the amount of money available for making improvements. In 6 months or a year, the situation may have changed, and the idea may be welcomed and adopted upon re-presentation. If the idea is presented the second time by another individual, the one who first presented it has a natural tendency to feel discouraged. He must ward off this feeling by recognizing that conditions change and that fresh angles of presentation often lead to the adoption of old ideas. The best antidote against discouragement is to go out and discover another idea. Solving problems and originating suggestions bring satisfaction to the type of men who are in supervisory positions and help to make the daily job more interesting.

CHAPTER III

LIMITATIONS OF OPERATION ANALYSIS

In considering the subject of operation analysis, the first question that naturally arises is that of the field to which the technique is applicable. There is a general recognition of the fact that methods-engineering principles have been applied to a wide variety of work, but a general realization of this nature is not sufficient for a man who wishes to know what value operation analysis and the subsequent steps of methods study have for his own particular product. Therefore, it will be desirable to consider the kinds of work to which operation analysis can be applied with beneficial results and to define the limits of its application.

Our Work Is Different.—The feeling which is undoubtedly most prevalent in the mind of the employer or supervisor who is acquainted only in a general way with the subject of methods engineering is that, although operation analysis has unquestionably accomplished worth-while results in certain lines of work or in certain industries, it has no value in his own particular line of work. Time and again the methods engineer hears such statements as, "That undoubtedly is fine for the work of the Blank Company, but our work is different. Therefore, methods study is impractical."

The fact which illustrates the utter lack of basis for this feeling is that it makes no difference what "our work" is. If it happens to be of a jobbing or small-quantity nature, it is felt that the field of operation analysis is limited to mass production. If a plant is engaged in turning out a single product, it is felt that operation analysis is more useful where the work is more varied. A foundry feels that the technique is more applicable to a machine shop, and the machine shop feels that it is useful chiefly in assembly work. Indeed, so universal is this feeling that the technique applies to all kinds of work but the kind which is under consideration that the methods engineer expects a prompt expression of it as soon as the subject of methods engineering is raised and, incidentally, is seldom disappointed.

Wherever the methods-engineering technique has been properly applied by a competent engineer, beneficial, almost spectacular, results have been obtained. This, if it were generally known, should do much to offset the feeling described above. The principles of methods engineering are fundamental, and they can be applied to any class of work. It makes no difference if a plant is manufacturing toys, tools, trains, or tractors; the principles apply equally to all.

The reason for this is that all work may be resolved into terms that are more or less basic. During operation analysis, one of the points that are considered is the purpose of the operation. It is just as useful to consider the purpose of grinding a part that goes inside a large steam turbine as it is to consider the purpose of the bending of a part that fits in an agricultural machine. It is as important to analyze the inspection requirements of a toy shovel as it is to analyze those of a gear bushing. The inspection requirements partly determine the operations that must be performed in either case and hence should be gone into carefully. Material handling presents problems that must be solved whether the product handled is bread, tooth paste, shoes, or patent medicine.

Working methods present points of remarkable similarity when closely analyzed. This may be clearly illustrated by the following example, which is given because of the ease with which it may be understood and in spite of the fact that it is not a practical industrial example of the application of methods study. The work of a bookkeeper who keeps account of expenditures and receipts and the work of an order clerk who receives incoming orders and writes out material requisitions accomplish entirely different results. The qualifications for the jobs are different, and the daily routine is not at all the same. When the work is carefully studied, however, points of similarity begin to appear. Each worker is seated at a desk. Each has papers to handle. Each uses pens, ink, pencils, erasers, and so on. Each spends part of his time writing.

Because handling papers and equipment requires the use of physical motions, it is reasonable to suppose that of all the ways in which these can be handled there is one way which will involve the fewest, quickest, and least fatiguing motions. Since time spent in making ineffectual motions is time wasted, it will prove worth while to study the layout of the desk and equipment.

To start with the bookkeeper, when the motions which he employs in the course of his work are analyzed it is found that it is necessary for him to move a pencil the distance of 1 foot many times a day. He cannot keep his pencil in his hand all day. Therefore, when he wants it, he must move to get it. When he is through with it, he must move it aside. If he is to locate the pencil quickly, it should be definitely positioned in a place where it can be secured most easily and quickly. Where is that place?

The traditional clerk usually kept his pencil behind his ear. This is really a quite convenient place. The motion required to

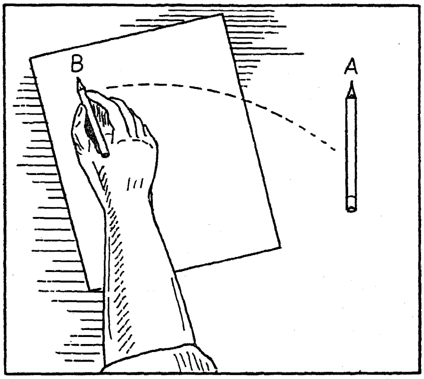


FIG. 4.—The location of any object relative to the point of use is governed by the fundamental principles of motion time.

get the pencil or return it is not unduly long, and the pencil is out of the way when not required. Not everyone, however, has the type of ear that makes a successful pencil holder; and in recent years, pencils behind the ear have gone out of style. Therefore, in laying out the desk of the bookkeeper, the pencil will be placed on the desk. Analysis shows that it should be kept 12 inches away from the point of use in order to have it out of the way and yet conveniently near when wanted.

With this point established, the next step is to determine the exact location of the pencil. Merely saying that it should be 12 inches from the point of use is not enough, for it may be 12 inches to the right or 12 inches to the left or 12 inches in front or anywhere in between. Now, a 12-inch motion can be made in two different ways. It can be made by moving the arm about

the elbow as a pivot, or it can be made by moving the arm about the shoulder as a pivot. Experiment and study will show that the first method is the better. Therefore, the pencil should be located at the point *A*, Fig. 4, which is the point from which the pencil can be moved to the point of use *B* with the elbow acting as a pivot.

As the result of this careful analysis and study, the best position for the pencil on the bookkeeper's desk has been determined. When this has been done, the bookkeeper finds that he can work to better advantage throughout the day. He gets his pencil easily and quickly and loses no time hunting for it, because it is always in the same place. He is much pleased with the results and is happy to commend the benefits that methods study has brought to him.

Now let us assume that an offer is made to improve the layout of the order clerk's desk in the same way. He listens carefully to an explanation of the kind of changes that can be made and studies the testimonial of the bookkeeper. In the end, he shakes his head and says, "No doubt, that worked very well for the bookkeeper. You see, however, my work is different. Instead of a pencil, I use a fountain pen. Therefore, it will not work for me."

It may seem that the example is farfetched; but presented in this way, it is seen how baseless the "our-work-is-different" attitude is. Very little work is identical, but in these two cases the differences are only surface differences. The fundamental principles underlying the work are the same. The point that a fountain pen is used instead of a pencil has nothing to do with the fact that under no-load or light-load conditions a 12-inch motion can be made more quickly when the elbow acts as the pivot than when the shoulder performs that function. The principle lies deeper than the nature of the object transported and applies to all lines of endeavor. The motion made by a mechanic in reaching for a screw driver is the same as that used by a sewing-machine operator in reaching for a pair of scissors or by a fitter in reaching for a piece of material or by a molder in reaching for his rammer or, for that matter, by a dentist reaching for his chisel. If one can be shortened and made less fatiguing, the others can also.

Although this discussion has thus far been confined to small objects, it applies equally to large parts. The problems involved

in lifting a ladle of molten metal with a crane are the same regardless of whether the metal happens to be copper, iron, or steel. Castings and forgings both present handling problems that are related. Countless similar examples can be taken from all types of industry.

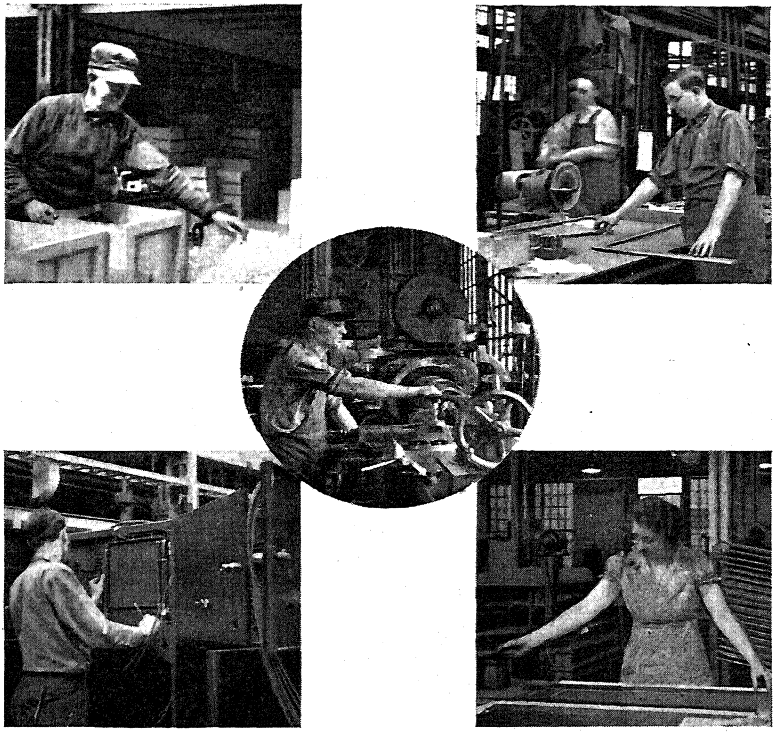


FIG. 5.—Analysis of operations in terms of motions reveals many points of similarity. Regardless of the object reached for, reaching motions are similar.

Hence, it may be seen that the application of the principles of job analysis is not limited by the nature of the product. In view of the prevalence of the "our-work-is-different" attitude, this point cannot be too highly stressed.

Effect of Quantity on Field of Operation Analysis.—If a large number of man-hours are expended upon a certain line of work, a 1 per cent saving may be important, whereas a 10 per cent saving on inactive work might not offset the cost of making the

study. Hence, it is almost axiomatic that it is more profitable to study the work with the greatest activity. This does not mean, however, that only mass-production work can be studied, for activity is measured on a line of work taken as a whole rather than on single jobs.

An operation may be repetitive from the viewpoint of the methods engineer in so far as analysis is concerned even though the quantities in which individual parts are made are quite small. This viewpoint is different from that which considers a job repetitive only when a large number of duplicate parts are produced.

For purposes of analysis, the methods engineer looks at an operation not as a single quantity but rather as a series of elemental operations. Therefore, when a number of different but similar jobs are reduced to their elements, it is found that several of the elements are common to all jobs. If an element is shortened on one job, it may be shortened on all jobs in which it occurs, and thus a saving is obtained over the entire line of work that may be of great magnitude.

Jobs that are molded on the bench in a foundry are not considered as being repetitive. Any one casting that was ordered in quantities would be made on a molding machine. However, if several bench molders work continuously at making molds, the operation will be considered as repetitive by the methods engineer.

The first operation performed by a bench molder in beginning to put up a mold is "place match or molding board on bench." If a standard flask is used and 10 molders put up 20 molds per day on the average, the operation will be performed 200 times per day or 60,000 times a year. Hence, it may be seen that under these conditions, the element "place match or molding board on bench" is truly a repetitive operation. It will be worth while to study the location of the molding boards and the motions used for handling them. If by careful analysis of the type described for laying out the bookkeeper's desk the time required to place the match or molding board is reduced from 0.0030 to 0.0015 hour, 0.0015 × 60,000 or 90 hours per year will be saved. This at an average bench molder's rate will amount to a worth-while total.

Similarly such elements as "place drag," "apply parting sand," "fill riddle," and so on, are repetitive elements. They occur on

every mold made and are not affected by the nature of the patterns in the mold. Hence, it will be profitable to consider each of these elements in detail, for any improvement made will apply to the entire bench-molding activity.

Certain elements vary with every job. Therefore, they are not repetitive in the sense that the element "place match or molding board on bench" is repetitive. The variation is in degree rather than in kind, however, and hence even the variable elements

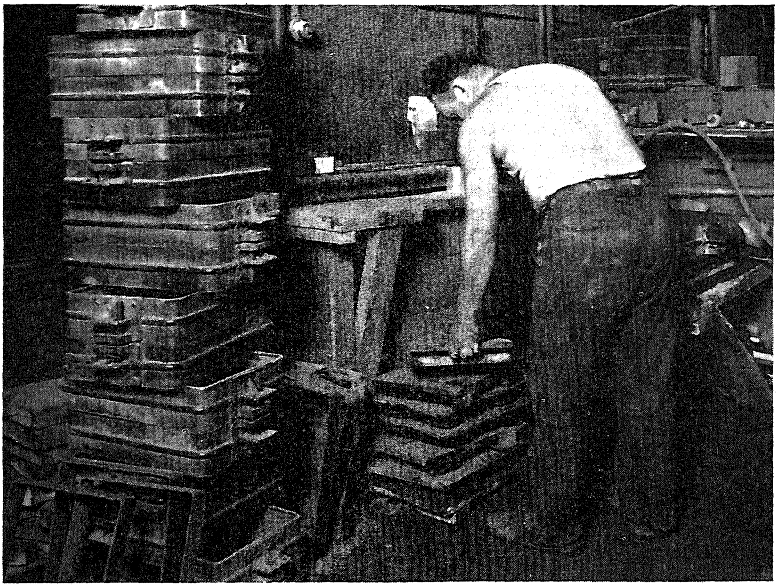


FIG. 6.—A bench molder produces a wide variety of work but many of his motions are repetitive and hence may be profitably subjected to detailed study.

have repetitive characteristics. When a mold must be reinforced with nails, the time for the element "reinforce mold" will vary with the number of nails placed. However, the same motions are used whenever a nail is placed, and hence an improvement in the method of securing and placing a nail will amount to a sizable saving in the bench-molding work as a whole.

This same principle applies to all lines of work. Machine work even in the jobbing shop is repetitive if the machines work steadily. Most machine work may be reduced to less than 100 elements which are repeated over and over again.

Therefore, it will be seen that operation analysis is not limited to large-quantity work but may be applied to advantage to any line of work on which a fair number of man-hours are expended. Usually, if a line of work has not been studied with the modern analysis approach, it is profitable to study it if one or more men are engaged full time upon it.

Class of Work to Which Operation Analysis Is Not Applicable. If job-analysis methods may be applied to any product and to all lines of work requiring the full-time services of one or more men, it follows that the only work to which it is not applicable is that which occupies only part of the time of one individual. A general machine shop may possess a broaching machine to take care of special jobs. If jobs requiring broaching are so infrequent that the machine operates only two days a month, detailed study of the operation will not be economically justified.

CHAPTER IV

TYPES OF METHODS STUDY

There are several techniques or procedures that may be used in making a methods study. These are illustrated graphically by Fig. 1 of Chap. I. All the procedures are not used every time a methods study is made, however, for only certain classes of work justify a complete and detailed study. The more detailed the study, the greater the amount of time required to make it. With any study, the savings effected must equal or exceed the cost of making the study if the expenditure is to be justified from an economic standpoint.

At the outset of methods study, therefore, the problem of determining the kind and the amount of study that are justified must be solved. From a general standpoint, the owner or the manager of a plant who contemplates beginning or extending its methods-engineering work must decide how thorough a study should be made in order to bring about the greatest return. More specifically, before beginning the actual work the methods engineer must determine his study procedure on the basis of expected returns. These decisions cannot be made offhand with any pretense at correctness, for there are a number of factors that must be considered. It is the purpose of the next two chapters to discuss these factors and to describe a procedure by which the owner, manager, superintendent, foreman, or methods engineer can determine with reasonable exactness the type of methods study that can be undertaken profitably for any class of work or for any individual job. This procedure has been found to be a practical if empirical approach to the mapping out of a methods-engineering program.

Types of Methods Study.—There are a large number of combinations that can be made of the various techniques used by the methods engineer, and it might seem that there are an equally large number of types of study that are commonly used. The problem is not so complicated as this, however, for certain

techniques naturally accompany certain other techniques. It would be possible to make an elaborate motion-picture study of a job and then without operator instruction set a time or a money allowance on the newly developed method by estimate. This would not be a practical combination, however; for as has already been said, the highly refined methods that are developed as the result of careful motion study must be taught to the operator if it is expected that the method will be followed. If the job justifies careful motion study, it also justifies careful measurement of the time element.

Thus it is found that the types of methods study commonly employed throughout industry fall into six major classes. The type that can economically be employed for the study of any job or class of work depends upon a number of conditions which are discussed in the next chapter. When a given type is decided upon, however, certain combinations of procedures are definitely indicated.

The six types of methods study and the procedures used for each are as follows:

Type

A. Written job analysis using one or more types of process charts and analysis sheets.
   Motion study employing motion pictures.
   Motion time study.
   Standardization including motion-picture training.
   Time study.

B. Written job analysis using analysis sheets.
   Motion study by analysis and observation.
   Standardization including written instructions.
   Time study.

C. Mental job analysis.
   Standardization including verbal instructions.
   Time study.

D. Written job analysis of class of work using process charts and analysis sheets for analysis of representative jobs.
   Motion study of representative jobs, usually employing motion pictures to determine best methods.
   Standardization including written instructions.
   Time study.
   Time formula.

E. Mental job analysis during general survey of work.
   Motion study by analysis and observation during general survey.
   Standardization.

Time study.
Time formula.
F. Standard data.

Types A, B, and C are applied particularly to individual jobs. Types D and E are applied to classes of work comprised of similar jobs, and type F is applied to either individual jobs or classes of work where quantities are very small.

In order to give a general picture of the steps of which the various types of methods study are composed, a brief description of each type of study, illustrated by an example, follows. Much

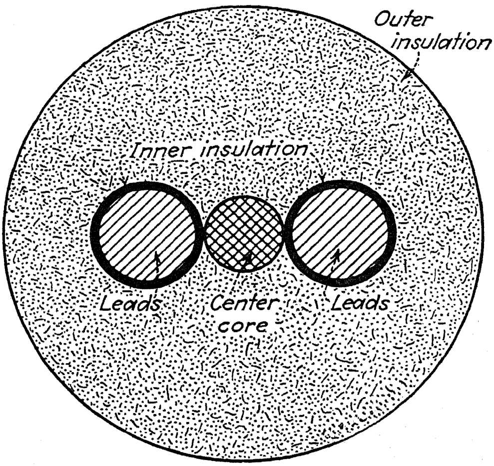


FIG. 7.—Cross-sectional view of battery cable.

will of necessity be left unexplained about the details of the techniques, for it is the intention at this point to present only the general aspects of the work.

Type A Methods Study.—The methods study which has been classed as type A goes into the job in the fullest detail. Every aspect is considered minutely. As a consequence, the largest percentage of savings may be expected to result from a study of this kind. The cost of making the study is at the same time relatively high so that this thoroughness is justified on but a limited class of work.

In a certain plant, the operation of removing the outer insulation from the ends of a 49-inch electric-battery cable was

subjected to a type A methods study after a brief survey of the job had indicated that this type of study would be profitable.

This battery cable is made by molding a heavy rubber covering around two rubber-covered leads which are twisted tightly together. A cross-sectional view of the cable appears enlarged as in Fig. 7. The operation consisted of removing the heavy outer insulation from the ends of the cable so that the inner wires could be straightened and used for making an electrical connection. The steps of the study that was made of the operation were as follows.

An analysis of existing conditions was first made. All operations performed on the cable were done at the same bench so that it was not considered necessary to study the flow of material with a flow process chart. An analysis sheet describing the conditions of the operation was filled in as shown by Figs. 8 and 9.

This preliminary job analysis showed certain facts about the job. The operation of removing the outer insulation as it was then being performed was a hand operation. A wooden gage located on the top of the bench was used to measure the point at which the heavy rubber insulation should first be scored. The scoring was done with a pair of scissors by rotating them about the cable. It was desirable to avoid nicking the inner insulation that covered the two leads, but investigation showed that on 90 per cent of the cables the inner insulation was cut through. The thickness of the outer insulation varied because of the shape of the twisted leads, and it was apparently impossible for the operator to judge the depth of scoring sufficiently to avoid this damage.

After scoring, a 1/8-inch slit was cut in the heavy outer insulation at the point of scoring. This was done for the purpose of obtaining a gripping point for the pliers with which the insulation was pulled off. The rubber curled up slightly after slitting; and by grasping it with the pliers, it could be removed with a peeling motion.

The method obviously was not good, and a number of initial investigations and experiments were made in an attempt to improve it. Various types of stripping machines then in existence were investigated, but because of the peculiar construction of the battery cable none would do the job. A scoring fixture using razor blades was tried, but it did not work satisfactorily.

Date August 1, 1937 Dept. C-11 Dwg. Sub.
Mould Die Style Item
Pattern Ins. Spec. L. Spec. Sub.
Part Description 49" Battery Cable

Operation Remove Insulation from Short End of Cable Operator Ferguson

DETERMINE AND DESCRIBE	DETAILS OF ANALYSIS
1. PURPOSE OF OPERATION Remove heavy insulation to make leads to fasten cable to lamp cover.	Can purpose be accomplished better otherwise?
2. COMPLETE LIST OF ALL OPERATIONS PERFORMED ON PART (see list below)	Can oprn. being analyzed be eliminated? be combined with another? be performed during idle period of another? Is sequence of oprns. best possible? Should oprn. be done in another dept. to save cost or handling?
3. INSPECTION REQUIREMENTS a—Of previous oprn. Material received from supplier in 49" lengths. Inspected in receiving department for count, length, and quality. b—Of this oprn. Outer rubber covering must be cleanly removed a sufficient distance back to give leads 1-1/4" long. c—Of next oprn. Leads must be 1-1/4" long.	Are tolerance, allowance, finish and other requirements necessary? too costly? suitable to purpose?
4. MATERIAL #16 - 2 Conductor Battery Cable Cutting compounds and other supply materials	Consider size, suitability, straightness, and condition. Can cheaper material be substituted?
5. MATERIAL HANDLING a—Brought by Truck b—Removed by Operator c—Handled at work station by Operator	Should crane, gravity conveyors, totepans, or special trucks be used? Consider layout with respect to distance moved.
6. SET-UP (Accompany description with sketches if necessary) Operator is seated in a properly adjusted chair with wide seat, back rest, foot support. Bundle of 25 cables is placed on bench to left. Block gage described on analysis sheet of this operation dated 7/20/37 is used to locate correct point at which insulation must be cut. Finished cables are laid across operator's lap. a—Tool Equipment Present Scissors and pliers. Suggestions Skinning fixture recommended to tool designer 8/27/37 Built 9/15/37 In operation 9/17/37	How are dwgs. and tools secured? Can set-up be improved? Trial pieces. Machine Adjustments. **Tools** Suitable? Provided? Ratchet Tools Power Tools Spl. Purpose Tools Jigs, Vises Special Clamps Fixtures Multiple Duplicate

No.	Description	Work Sta.	Dept.
1.	Remove insulation from short end	Bench	C-11
2.	Cut leads to length	Bench	C-11
3.	Skin leads	Bench	C-11
4.	Clamp on terminal clip	Bench & Fixture	C-11
5.	Remove insulation from long end	Bench	C-11
6.	Cut leads to length	Bench	C-11
7.	Skin leads	Bench	C-11
8.	Clamp on terminal clip	Bench & Fixture	C-11
9.	Tape both ends of cable	Bench	C-11
10.	Tin terminals	Solder Pot	C-11
11.	Tie in bundles of 25	Bench	C-11

Methods Engineering Council
Form No. 101 ANALYSIS SHEET

FIG. 8.—Front of analysis sheet for battery-cable skinning operation.

7. CONSIDER THE FOLLOWING POSSIBILITIES.

	RECOMMENDED ACTION
1. Install gravity delivery chutes.	Not practical
2. Use drop delivery.	How used
3. Compare methods if more than one operator is working on same job.	Have done so
4. Provide correct chair for operator.	Has been done
5. Improve jigs or fixtures by providing ejectors, quick-acting clamps, etc. In Use 9/17/37	Fixture suggested 8/27/37
6. Use foot operated mechanisms. Arranged 9/17/37	Fixture suggested 8/27/37
7. Arrange for two handed operation.	Yes, if fixture works
8. Arrange tools and parts within normal working area.	New set-up to be made
9. Change layout to eliminate back tracking and to permit coupling of machines.	No application
10. Utilize all improvements developed for other jobs.	Have done so

8. WORKING CONDITIONS

Satisfactory

a—Other Conditions

Manufacturing quantities, 4,000 per month

Light
Heat
Ventilation, Fumes
Drinking Fountains
Wash Rooms
Safety Aspects
Design of Part
Clerical Work Required (to fill out time cards, etc.)
Probability of Delays
Probable Mfg. Quantities

9. METHOD (Accompany with sketches or Process Charts if necessary)

a—Before Analysis and Motion Study.

1. Pick up cable
2. Position cable in gage
3. Position scissors in gage
4. Score insulation
5. Cut insulation 1/8" at scoring
6. Lay aside scissors and pick up pliers
7. Pull off insulation with pliers
8. Lay aside cable and pliers

b—After Analysis and Motion Study

1. Pick up cable
2. Place in skinning fixture
3. Skin cable
4. Lay cable aside

Arrangement of Work Area
Placement of
Tools.
Materials.
Supplies.
Working Posture
Does method follow Laws of Motion Economy?
Are lowest classes of movements used?

See Supplementary Report Entitled

Date

OBSERVER J. C. Smith APPROVED BY W. W. Boyd

FIG. 9.—Back of analysis sheet for battery-cable skinning operation.

It was still necessary to slit the insulation by hand and pull it off with pliers, so that even if the scoring fixture had done a satisfactory job little time would have been saved.

Although analysis alone showed that the operation was not particularly efficient, it did not suggest better methods. Accordingly, a more detailed study was made by means of motion pictures. A few cycles of the operation were photographed; and as soon as the film had been processed, a detailed film analysis was made. The operator process chart that was drawn up of one of the cycles is shown by Fig. 10; and a time study of the method, taken for record purposes while the return of the film was being awaited, is shown by Figs. 11 and 12.

The operator process chart served to confirm what was already suspected, that is, that the method was highly inefficient. The left hand performed a "hold" operation during the major part of the cycle, and the right hand had entirely too much positioning.

Intensive study was given to ways and means of improving the method. It was seen that improvement could not be made merely by rearranging the layout or the motion sequence but that an entirely different method which might call for the invention of a hitherto undeveloped type of skinning fixture might be required. While seeking a different method for doing the job, the methods engineer examined a piece of the heavy outer insulation that had been removed. He saw that the inside of this insulation was deeply corrugated as the result of being molded around the twisted wires. It was these corrugations which made it so difficult to remove the insulation with a straight pull and necessitated the peeling operation that was being used.

Further examination disclosed the fact that the corrugation resembled a molded thread. This suggested that instead of being pulled off the insulation should be removed with a twisting or unscrewing motion. A few trials by hand showed that this would probably work. It was then a simple matter to determine the practicability of the idea by experimenting with a chuck held in a drill press. A cable was lightly scored. It was then clamped in the chuck of the drill press. The drill press was started, and the cable was given a steady pull. The insulation unscrewed, as expected, leaving the leads undamaged.

The plant tool designer was next approached and asked to design a fixture that would perform the operation of unscrewing

DATE August 16, 1937 DEPT. C - 11 DRAWING Item or Part No.

PART DESCRIPTION 49" Battery Cable

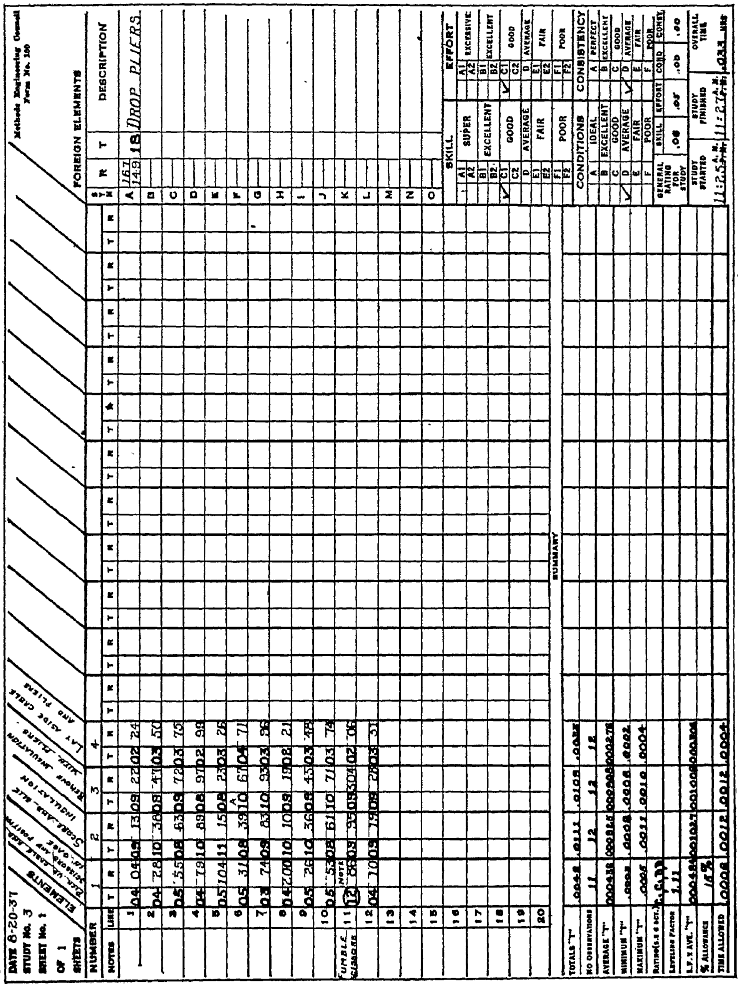
OPERATION Remove Insulation from Short End of Battery Cable FILM SPEED 16 Frames/Second

LEFT HAND	SYMBOL	MOTION CLASS	TIME	MOTION CLASS	SYMBOL	RIGHT HAND
Grasp cable	G	1		1	G	Grasp scissors
Move cable to gage	TL	3	0001	3	TL	Move scissors to gage
Hold cable	H			2	P	Position scissors
			0002			
			0003			
Move cable and scissors to cutting position	TL	4		4	TL	Move cable and scissors to cutting position
			0004			
			0005			
			0006			
			0007			
				4	U	Score insulation
			0008			
			0009	4	PP TL	Move scissors to slitting position
			0010			
			0011			
			0012	2	P	Position scissors
				2	U	Cut insulation 1/8"
			0013	4	TL	Move scissors aside
				1	R	Release
			0014	3	TE	Move to pliers
				1	G	Grasp pliers
			0015			
			0016			
			0017	3	TL	Move pliers to position
			0018			
			0019			
			0020	2	P	Position pliers in slit
				2	G	Grip insulation with pliers
			0021			
Hold cable	H			4	U	Pull insulation off
Release	R	1	0022			
Idle	UD		0023	4	TL	Move pliers aside
				1	R	Release
Move to next cable	TE	3	0024	3	TE	Move to scissors

Methods Engineering Council, Inc. Form No. 109 — OPERATOR PROCESS CHART — Sheet No. 1 of 1 Sheets

FIG. 10.—Operator process chart of old method of skinning battery cable.

the insulation after scoring. He suggested combining a scoring tool with the fixture, a suggestion that was at once adopted.



DATE 8-20-37 STUDY No. 3 SHEET No. 1 OF 1 SHEETS — Methods Engineering Council Form No. 100

ELEMENTS: 1. Pick up cable and scissors and position 1st. base; 2. Score and slit insulation; 3. Remove insulation with pliers; 4. Lay aside cable and pliers

NOTES	LINE	1 T	1 R	2 T	2 R	3 T	3 R	4 T	4 R
	1	04	04	09	13	09	22	02	24
	2	04	78	10	38	08	47	03	50
	3	05	55	08	63	09	72	03	75
	4	04	79	10	89	08	97	02	99
	5	05	104	11	15	08	23	03	26
	6	05	31	08	39	A 10	67	04	71
	7	03	74	09	83	10	93	03	96
	8	04	200	10	10	09	19	02	21
	9	05	26	10	36	09	45	03	48
	10	05	53	08	61	10	71	03	74
FUMBLE SCISSORS	11	12	NOTE 86	09	95	09	304	02	06
	12	04	10	09	19	09	28	03	31
	13–20								

SUMMARY

	1	2	3	4
TOTALS "T"	.0048	.0111	.0108	.0033
NO. OBSERVATIONS	11	12	12	12
AVERAGE "T"	.000436	.000925	.000900	.000275
MINIMUM "T"	.0003	.0008	.0008	.0002
MAXIMUM "T"	.0005	.0011	.0010	.0004
RATING (S. E. C. CY.)	C, C, D, D			
LEVELING FACTOR	1.11			
L.F. × AVE. "T"	.000484	.001027	.001000	.000305
% ALLOWANCE	15%			
TIME ALLOWED	.0006	.0012	.0012	.0004

FOREIGN ELEMENTS

SYM	R	T	DESCRIPTION
A	167 / 149	18	DROP PLIERS

SKILL: C1 GOOD ✓; EFFORT: C1 GOOD ✓; CONDITIONS: D AVERAGE ✓; CONSISTENCY: D AVERAGE ✓

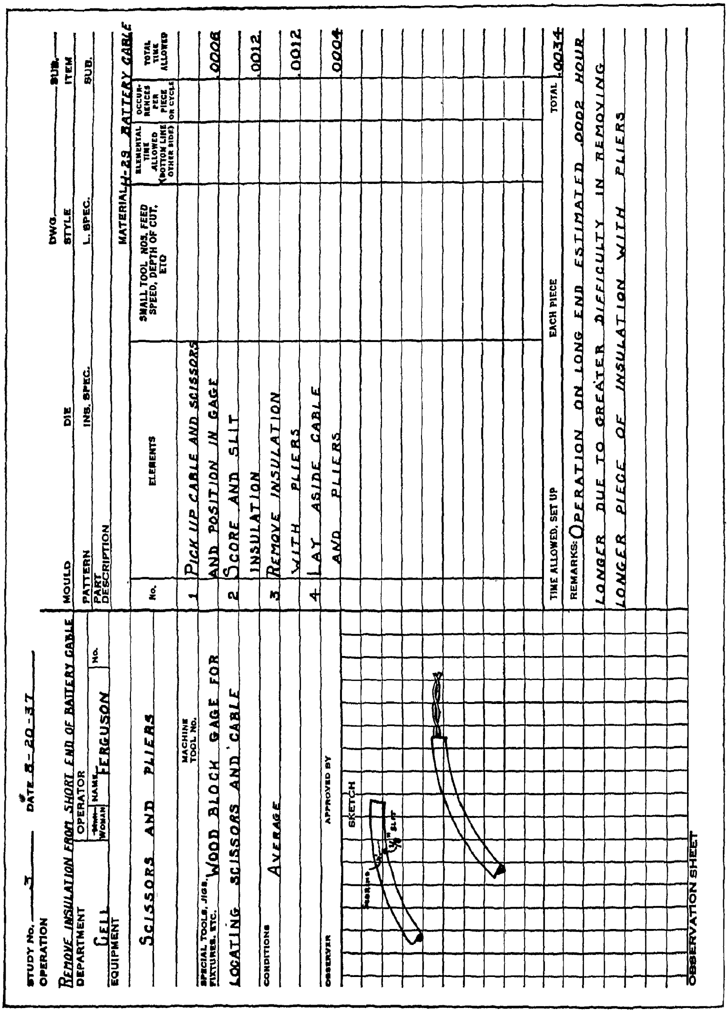
GENERAL RATING FOR STUDY: SKILL .06, EFFORT .05, COND. .00, CONSY. .00

STUDY STARTED 11:25 A.M.; STUDY FINISHED 11:27 A.M.; OVERALL TIME .033 HRS.

FIG. 11.—Front of time-study observation sheet for old method of skinning battery cable.

After the tool was built, the new operation was as follows. The tool was mounted on the shaft of a ¼-horsepower electric motor. With the motor shut off, the end of the cable was inserted in the fixture, a funnel-shaped guide minimizing position-

ing during this operation. With the cable in position, the operator stepped on a foot treadle and, after a pause, pulled the cable. As the treadle was depressed, the motor started.



STUDY No. 3 DATE 8-20-37

OPERATION: REMOVE INSULATION FROM SHORT END OF BATTERY CABLE

DEPARTMENT: CELL — OPERATOR: WOMAN — NAME: FERGUSON — No.

EQUIPMENT: SCISSORS AND PLIERS

MACHINE TOOL No.

SPECIAL TOOLS, JIGS, FIXTURES, ETC.: WOOD BLOCK GAGE FOR LOCATING SCISSORS AND CABLE

CONDITIONS: AVERAGE

OBSERVER — APPROVED BY

SKETCH

MOULD — DIE — DWG. — SUB.

PATTERN — INS. SPEC. — STYLE — ITEM

PART DESCRIPTION — L. SPEC. — SUB.

MATERIAL: H-29 BATTERY CABLE

No.	Elements	Small tool, nos. feed speed, depth of cut, etc.	Elemental time allowed (bottom line other side)	Occurrences per piece or cycle	Total time allowed
1	Pick up cable and scissors and position in gage				.0006
2	Score and slit insulation				.0012
3	Remove insulation with pliers				.0012
4	Lay aside cable and pliers				.0004
	Time allowed, set up	Each piece		Total	.0034

REMARKS: OPERATION ON LONG END ESTIMATED .0002 HOUR LONGER DUE TO GREATER DIFFICULTY IN REMOVING LONGER PIECE OF INSULATION WITH PLIERS

OBSERVATION SHEET

FIG. 12.—Back of time-study observation sheet for old method of skinning battery cable.

Further depression of the treadle brought the scoring tool into operation, lightly scoring the cable. Still further depression of the treadle caused three jaws to grasp the insulation. The rotary

motion of the motor coupled with the pulling on the cable by the operator unscrewed the insulation from the cable. When the treadle was released, the motor stopped, and a spring within the tool ejected the scrap insulation.

With this method, it was a simple matter to arrange for two-handed operation. Two motors and tools were placed side by side on the workbench. The operator worked as follows. At the start of the operation, she laid a bundle of cables across her lap. She grasped one at the middle and slid her hands out to the end while moving to the tools. She inserted the ends in the fixtures, stepped on the treadle, and pulled. The result was a completely skinned cable which was laid aside by dropping on a rack in front of her as she returned for the next cable.

In making the workplace layout, the matter of motion times was carefully considered. The tools and the cables were arranged so that the operation could be done principally with short fourth-class motions, the most practical for this job.

When the job was developed, an operator was carefully trained to do the work with no unnecessary motions. When she became proficient, a motion picture was taken and was subsequently used to train other operators who performed the same work. To show the improvement that had been made, a cycle of the film was analyzed and the operator process chart shown by Fig. 13 was drawn. If necessary, this chart could also serve as an instruction sheet for operators.

When the new method was fully developed and an operator trained, accurate measurement of the time element was made by means of stop-watch time study. The resulting study is illustrated by Figs. 14 and 15. The time can, of course, be determined from the film; but operators who are used to time study usually prefer that allowances be set by this method, feeling that since the time study covers a large number of cycles it gives a more representative value.

The job just described gives a good indication of the detailed work required when making a type A study. The operation itself was comparatively simple, but the methods engineer spent the equivalent of several days on it. The saving, however, justified this work since the job was highly repetitive. By the old method, the time for skinning one end was 0.0034 hour and that for skinning the other end 0.0036 hour, a total of 0.0070 hour

DATE September 20, 1937 DEPT. C-11 DRAWING Item or Part No.

PART DESCRIPTION 49" Battery Cable

OPERATION Remove Insulation from Long and Short Ends of Battery Cable FILM SPEED 16 Frames/sec.

LEFT HAND	SYMBOL	MOTION CLASS	BODY	SHOULDER	FOREARM	WRIST	FINGER	TIME	FINGER	WRIST	FOREARM	SHOULDER	BODY	MOTION CLASS	SYMBOL	RIGHT HAND
Grasp cable	G	1												1	G	Grasp cable
								0001								
	PP							0002							PP	
	CD														CD	
Move to stripper	TL	4						0003						4	TL	Move to stripper
Insert short end of cable in stripper	A	4												4	A	Insert long end of cable in stripper
								0004								
Remove insulation	U	4												4	U	Remove insulation
Idle	BD							0005								
Move cable aside	TL	4												4	TL	Move cable aside
Release	R	1												1	R	Release
Move to next cable	TE	4						0006						4	TE	Move to next cable

Methods Engineering Council, Inc. Form No. 109 OPERATOR PROCESS CHART Sheet No. 1 of 1 Sheets

FIG. 13.—Operator process chart for new method of skinning battery cable.

per cable. By the new method, the time for the complete job was 0.0007 hour, a production increase of 900 per cent.

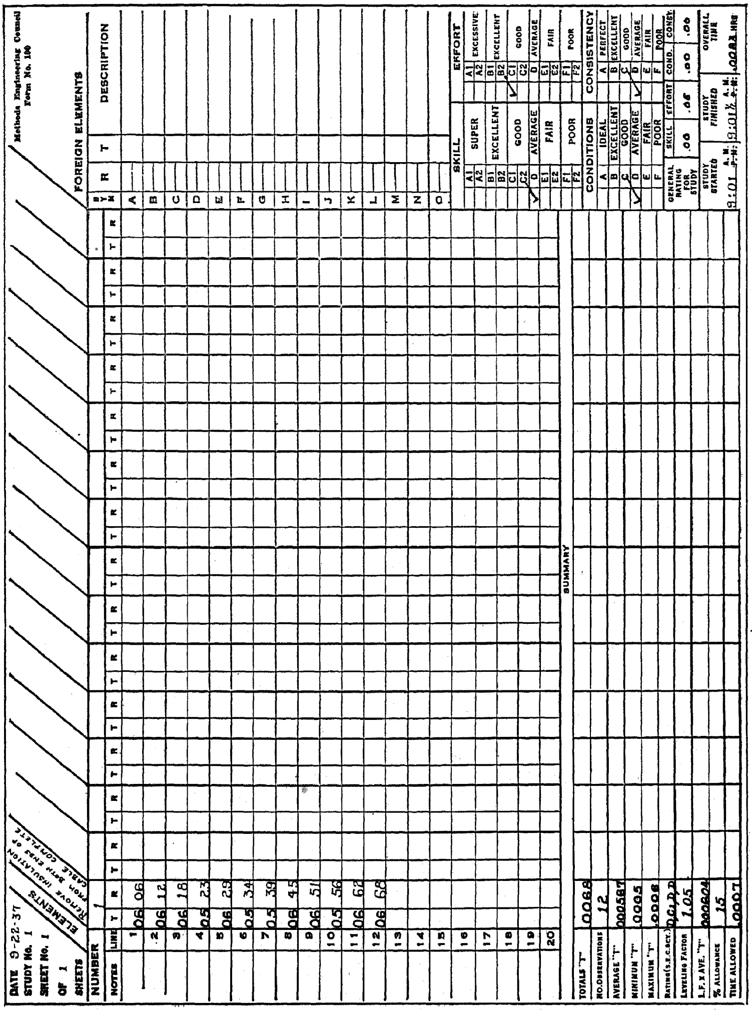
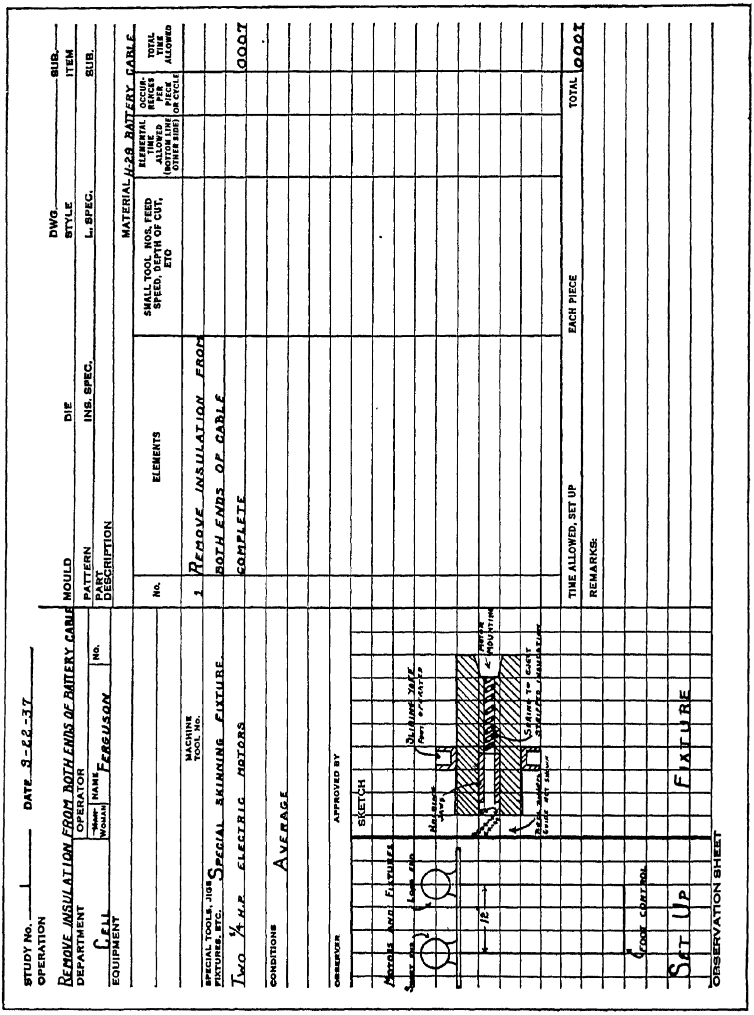


FIG. 14.—Front of time-study observation sheet for new method of skinning battery cable.

Type B Methods Study.—When a simple method of doing a job is once known, it looks so easy and so fundamentally correct that it is often difficult for those who have had no experience with methods study to understand how it could possibly ever

have been done otherwise. The tendency is to attribute older and less efficient methods to lack of interest, of effort, or of ingenuity on the part of the workers and their supervisors.


STUDY No. 1 DATE 9-22-37

OPERATION REMOVE INSULATION FROM BOTH ENDS OF BATTERY CABLE

DEPARTMENT CELL | OPERATOR MAN / WOMAN | NAME FERGUSON | NO.

MOULD | DIE | DWG. | SUB.

PATTERN | INS. SPEC. | STYLE | ITEM

PART DESCRIPTION | L. SPEC. | SUB.

EQUIPMENT | MATERIAL H-29 BATTERY CABLE

NO.	ELEMENTS	SMALL TOOL, NOS. FEED SPEED, DEPTH OF CUT, ETC	ELEMENTAL TIME ALLOWED (BOTTOM LINE OTHER SIDE)	OCCURRENCES PER PIECE OR CYCLE	TOTAL TIME ALLOWED
1	REMOVE INSULATION FROM BOTH ENDS OF CABLE COMPLETE				.0007
	TIME ALLOWED, SET UP	EACH PIECE		TOTAL	.0007

REMARKS:

MACHINE TOOL No.

SPECIAL TOOLS, JIGS FIXTURES, ETC. SPECIAL SKINNING FIXTURE

TWO 1/4 H.P. ELECTRIC MOTORS

CONDITIONS AVERAGE

OBSERVER | APPROVED BY

SKETCH

OBSERVATION SHEET

FIG. 15.—Back of time-study observation sheet for new method of skinning battery cable.

Efficient methods are easy methods, and it is difficult for the untrained to grasp the amount of detailed investigation that is necessary to evolve them.

Thus, now that a simple method is known for removing the outer insulation from the ends of the battery cables, it might seem that the same method could have been developed from a type B study. Since no flow process charts were required, the written-analysis work will be the same as for the type A study and the same inefficiencies will be noted in the old method. Should not then motion study by analysis and observation on the part of the trained observer lead to the same developments as the analysis of a motion picture of the job? In many cases the answer is probably "yes." The picture, however, aids analysis by presenting the operation in a convenient form for detailed study. Since more careful study is possible, greater results may be expected. Thus, although the type B study can be made more quickly than the type A study, it cannot be expected to accomplish so much.

This is clearly demonstrated by the battery-cable job. The job actually was motion-studied by analysis and observation before a picture was taken. In fact, the unsatisfactory results that were obtained were what led to the taking of the picture.

When the motions used for doing the job were observed and analyzed, the chief points noted were that the method of scoring the cable with scissors was inefficient and the fact that the pliers and the scissors were used alternately necessitated many motions which might be eliminated by some other method. The net result of this was to try scoring the cable with a razor-blade fixture, which did not work, and to suggest that a saving could be made if the scissors and pliers could be combined into one special tool. This tool would have gripping surfaces close to the cutting points, so that when the slit was cut the insulation would be grasped in the same motion and could be pulled off without changing tools and without performing another positioning. A better method of moving to the slitting positions was devised at the same time.

The latter suggestions appeared to be entirely practical and promised to effect worth-while savings, but it was seen that the operation would still be a one-handed operation. Therefore, because the desirability of two-handed operation was recognized, the greater detail of the type A study was resorted to.

In general, the improvements discovered by type B studies are more obvious than those discovered through type A studies and

require less inventive ability. The methods that are set up do not emphasize the path of each motion and all the details necessary to do the job in the minimum time; hence, written instruction sheets which are usually a list of elements—using the word in the time-study sense—are all that is furnished the operator. The final time allowance is set by accurate stop-watch time study.

Although the results that may be expected from type B studies fall short of those obtained from the A type, the former may be made much more quickly. Hence, the type B studies are applicable to many jobs that are repetitive but not enough so to justify lengthy study.

Type C Methods Study.—The type C methods study is the briefest form of individual detailed study that is made. The job is quickly analyzed mentally, and the obvious improvements that can be made are pointed out to the operator and are put into effect at once. The job is then time-studied without further delay. Because of the quickness with which it may be made, the type C methods study is the most practical type for work done in relatively small quantities. The chief benefit is obtained from getting the work on an incentive basis, and the savings that come from quickly made methods changes are of secondary importance.

To illustrate—in a shop doing punch-press work, an order was received that called for the blanking and forming of 5,000 small sheet-steel parts. The job would last only about 2 days, and it was uncertain whether or not it would ever be reordered. Consequently, the methods engineer decided that a type C study was all that was justified.

When the study was begun, the punch press had already been set up by the die setter, and the operator had done a few pieces. At a glance, the methods engineer sized up the workplace layout and the method being used. He noticed, for example, that the raw material was contained in a box which stood on the floor. The operator had to bend over every time he picked up a part. The part was put in the punch press with the right hand. Both hands were used to trip the press. On the return stroke, a stripper stripped the formed piece from the punch, and it together with the scrap from the blank fell loosely on the die. The operator picked up the piece and the scrap with both hands, separated them, tossed the scrap into a can to his left with his

left hand, and then transferring the finished piece from his right to his left hand laid it aside in a container to his left.

The methods engineer saw at once that this method could be improved. First, he secured a low table and placed it to the right of the operator. On it he set the box of raw material, tilted at an angle so that the operator could get at it easily. On the left of the operator, he arranged the scrap can and the finished-parts container in line. The finished-parts container was near the operator close to his feet, and the scrap can which was higher was on the far side of the finished-parts container.

He then instructed the operator to work as follows. As the finished part and scrap are stripped off the punch, the operator

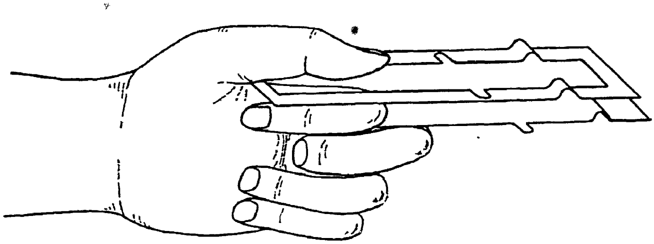


FIG. 16.—Method of grasping scrap and punching to permit disposal with fewest motions.

grasps them with both hands, his left thumb and forefinger holding one corner of the scrap. He separates the two parts by pressing the finished part downward through the scrap with his right hand. As the part comes through, he grasps it between the second, third, and fourth fingers and the back of the first finger of his left hand, as shown by the sketch, Fig. 16. Then as he moves his right arm to the raw-material container to get the next blank, he moves his left arm to the left. As his left hand passes over the finished-parts container, he releases the finished part. He continues the movement of his arm to the left and, when he nears the scrap can, releases the scrap with a tossing motion.

The new method is simple, and the operator becomes reasonably proficient at it after a few trials. It is easier than the old method, as he quickly discovers. After allowing the operator a few minutes to develop a rhythmic cycle, the methods engineer begins his study. He observes about 20 pieces and then going back to his desk rapidly works up the study. As soon as the

allowed time is computed, he tells the operator what it is. The making of the necessary records completes the job.

The procedure as described required about half an hour. As the result of his work, the methods engineer has made certain definite savings. On an incentive basis, the job would cost approximately \$8 if the operator's first method were used. On daywork, this method, of course, would have been followed; and on the basis of the usual difference between daywork and incentive performance, the job would have cost about \$13.40. Actually, with the new method in effect, the job cost \$4.80. Hence, placing the job on an incentive basis saved \$5.40 and improving the method saved \$3.20, a large saving for a brief mental analysis.

Type C studies have been widely used in the past, particularly where little emphasis has been placed on motion study. They give decidedly worth-while results, although they cannot be expected to accomplish as much as more detailed studies.

It should be noted in passing that the extent to which methods are improved during this type of study depends wholly upon the experience and the ingenuity of the observer and particularly upon his knowledge of and ability to apply the principles of motion study.

Types D and E Methods Study.—When many time allowances or piece rates must be established for a given class of work, time formulas can often be used to good advantage to simplify the work of the methods engineer. They permit him to establish a large number of accurate values without the necessity of taking detailed time studies.

It is sometimes thought that, because no actual time studies are taken, the methods engineer is merely doing a form of estimating when he applies a time formula. This is not the case. Time formulas are based upon time-study data and consist of these data arranged in a form that is convenient for quick interpretation and use. For example, the first element of many operations is "pick up part and put on table." When a formula is derived to cover all kinds of parts handled in a particular class of work, the methods engineer will make detailed time studies of a number of parts, covering the smallest and the largest and a number in between. As a result, he secures certain data that may be plotted to give a handling-time curve such as Fig. 17. When this curve has once been established, the methods engineer

is able to determine from it the time required to pick up any part coming within the weight range of his curve. The resulting time is not an estimate but an accurate, scientifically determined value.

When the conditions surrounding a given class of work are such that the derivation of a time formula is desirable, the methods that are being employed should be surveyed. If methods are good as the result of previous study of individual jobs, it will be advisable to proceed with the derivation of the formula at once. If not, as in the case of a line of work that has always been on

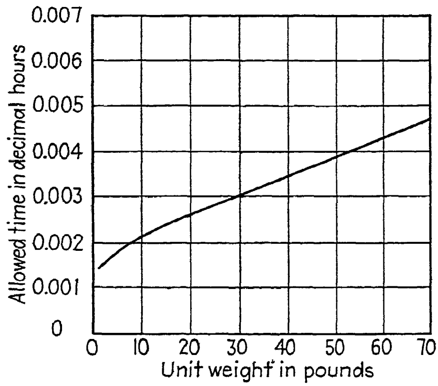


FIG. 17.—Handling-time curve for element "pick up part and put on table."

daywork, working methods must first be carefully studied. If it is advisable to study methods at all, it is usually worth while to go into considerable detail. Any improvements that are made will apply to many or all jobs handled; hence, savings in the aggregate are likely to be large.

The type D methods study, which is the formula-derivation procedure, preceded by detailed motion study, is likely to show greater results than the type E study in all but the most standardized lines of work and hence may be profitably employed in spite of the fact that its application may require a fairly long period of time, usually 2 to 6 months.

A good example of a type D methods study is furnished by an investigation undertaken in a large foundry engaged in producing castings from nonferrous alloys. The furnace crew who had the duty of melting and distributing metal were on daywork,

and it was fairly obvious that the work was not being performed efficiently.

Preliminary analysis brought to light the following facts. Seventeen different alloys were used, requiring several different melting procedures. The bulk of the metal was melted in Swartz open-flame oil-fired tilting type furnaces. Certain white-metal alloys with a low melting point were melted in crucibles in charcoal-fired pits. One highly volatile alloy was melted in an induction type electric furnace.

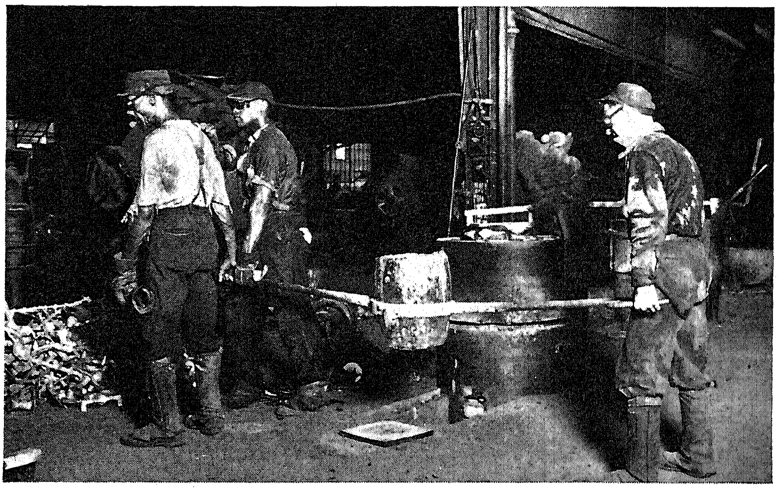


FIG. 18.—Old method of transporting 250-pound ladles of molten metal.

Melted metal was distributed for the most part in 250-pound ladles some carried by three men as shown by Fig. 18 and some by monorail trolley. Larger ladles handled by crane were used when pouring large castings.

At the time of the initial survey, the furnace group consisted of 23 men, 1 checker, and a foreman. The foreman kept in touch with the molders, and it was his duty to see that molten metal was available when needed. The checker weighed furnace charges, kept records of all metal melted, ordered new metal when needed, and assisted the foreman occasionally.

Of the 23 men, 10 attended to the furnaces. They weighed out charges, loaded the furnace, supervised the melt, poured the

finished metal into distributing ladles, and made minor furnace repairs.

The other 13 men distributed metal to the molders, kept ladles in repair, poured "sticks" in permanent iron molds which they set up themselves, and attended to a number of other lesser duties. An overhead monorail trolley system permitted ladles to be pushed to the various pouring stations. Three men were required to carry full ladles from the furnaces to the trolleys, and two men went with the ladle, one to push it along and later skim off the slag during pouring and the other to assist the molder during pouring. This second man had little to do; but because of the design of the ladle and the trolley system, his services were necessary.

It was noted during the survey that many members of the group were idle a good part of the time. Occasionally, all members of the group worked at the same time. At other periods, less than 25 per cent of the group were occupied. This suggested that there were certain rush periods followed by periods of comparative inactivity.

At this point, a more detailed study was begun. The records kept by the checker were obtained and analyzed. The checker kept a record of the time each furnace was charged and the time pouring began, in order to have this information should the metallurgist desire it. The number of pounds charged and the time charging was finished roughly established the length of time the furnacemen worked and the time of day at which these working periods occurred. The number of pounds charged and the time pouring started gave the same information on the ladle crews. The man-hours worked at all times of day were plotted graphically, and an average work curve for a period of 2 weeks similar to that shown by Fig. 19 was obtained. This curve showed definitely that there were fixed daily peaks and depressions in the work load.

The reasons for this were soon apparent. When the day began, all furnacemen started charging furnaces. For a while, they all worked hard. Then, all the furnaces being charged, there was a period of inactivity during which they did nothing but adjust the heat of the furnaces occasionally. The ladle men had nothing much to do from the time they arrived until pouring began.

Under this method of operation, all furnaces were ready for pouring at the same time. When pouring began, all members of the furnace group were very busy until the metal had been distributed and the furnaces recharged. Then followed another period of inactivity which lasted until the furnaces were again ready for pouring. These alternate waves of activity and inactivity followed one another throughout the day.

The molders continued to make molds until the working day ended. It was therefore necessary for the furnace crew to work overtime to pour off the molds, for none was allowed to stand

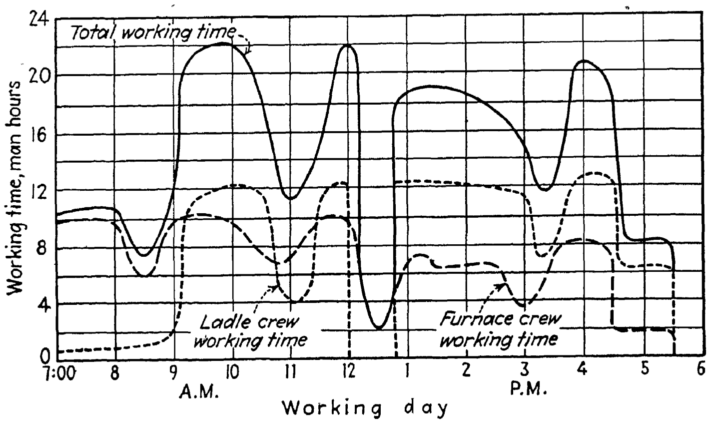


FIG. 19.—Average work curve for furnace operators in nonferrous alloy foundry before methods study.

unpoured overnight. The men were paid at the rate of time and one-half for all overtime work, and observation indicated that for this reason they were in no great hurry to finish work.

The survey showed that there were a number of possibilities for savings on this work. A type E study would, of course, bring about certain economies as the result of the introduction of incentives. A type D study, however, which would first consider improving working methods, would result in much greater savings and would be well worth while.

Accordingly, a type D study was made. Motion pictures were considered unnecessary as the work did not lend itself well to this type of study. Working methods were submitted to close study by analysis and observation; as a result, certain improve-

ments were made that brought about marked reductions in idle time and human effort.

The major improvements are easily described although it required about 2 months to work them out and install them. First, devices were constructed that enabled one man to handle the ladles. The ladle buggy shown by Fig. 20 was devised to transport the ladles between the furnaces and the monorail system, and the pouring rig illustrated in Fig. 21 permitted one

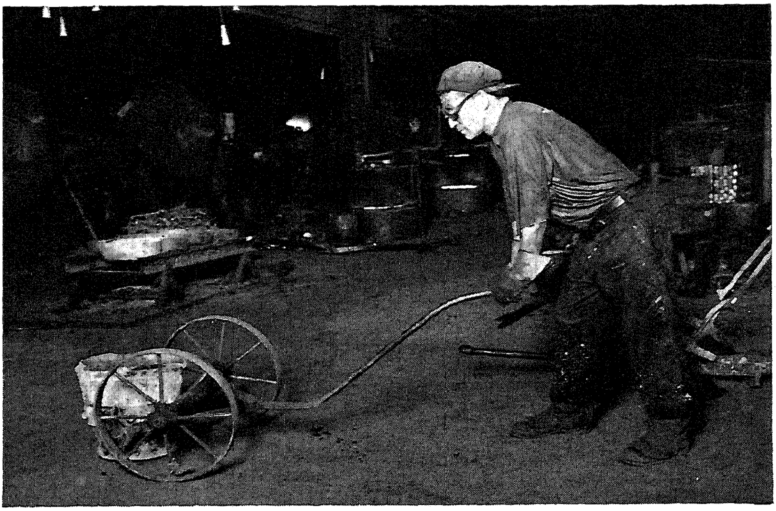


FIG. 20.—Ladle buggy which enables one man to transport 250-pound ladle of molten metal from furnaces to monorail system.

man to do the pouring. The devices were simple and effective; and after the furnace group had demonstrated to themselves their practicability, the number of men in the ladle crew was reduced from 13 to 5.

The peaks in the work load were leveled off by making a few simple changes in existing practices. Under the revised procedure, the work was done as follows. The night watchman lighted several furnaces about 6:00 A.M. This permitted them to become preheated before the furnacemen arrived at 7:00 A.M. When the furnacemen began work, they lighted the rest of the furnaces. They then charged the preheated furnaces, and when

these were charged the rest were preheated and ready for charging. When the second group was charged, the first group was ready for pouring. Thus the furnace crew could work all day fairly steadily, and their crew was reduced from 10 to 7 men.

The ladle men were not required to report for work until 8:00 A.M. By that time, the first furnaces were ready for pouring, so that they could begin work at once. To make up for the late start, the ladle men worked an hour after the regular work day

FIG. 21.—Pouring rig which enables one man to pour molds.

ended. During this time, they finished pouring the molds put up by the molders toward the end of the day. Besides enabling the ladle men to work more steadily, this procedure practically eliminated overtime-bonus payments.

As a result of this preliminary methods development, the group was reduced from 23 to 12 men. In addition, the foreman, because he had fewer men to direct and because the work proceeded more systematically, was able to take over the work of the checker. Thus it is seen that a study of methods brought decidedly worth-while returns.

The study from this point on took the course of a type E study; that is to say, a formula was developed that enabled the accurate computation of the labor involved in melting and distributing the metal required for any given casting. As a matter of history, this in itself was no easy task. The variables were many; and because it was necessary to base time allowances upon the weight of finished castings, it was first necessary to derive a formula which would make it possible to compute accurately the number of pounds of metal that had to be melted to produce a casting of any given weight, shape, or alloy. The formula was derived, however,[1] and has given accurate results for a number of years. The time allowances for the furnace group are accurately established, and the members of the group have a zest for the work that was noticeably lacking under the previous conditions. Finally, although it required nearly a year to complete this rather difficult installation, the yearly savings amounted to nearly $15,000.

Type F Methods Study.—The type F study is in reality no methods study at all but rather the quick application of some form of standard data for the purpose of setting a time or a money allowance on a nonrepetitive job. The standard data may be of almost any type. They may consist of written data compiled from stop-watch time studies, a file of previously established allowances used for comparison purposes, or comparatively unorganized mental data acquired by experience and used as a basis for estimating.

A time allowance used for wage-payment purposes should never be established by estimate based purely on judgment. An allowed time set in this manner is nearly always incorrect and leads to difficulties. The time allowance will be compared by the workers with other allowed times for similar work. If it is low, the workers will want it raised, and if it is high, they will want the other time allowances raised. Inconsistencies invariably cause trouble, and therefore estimates based upon judgment alone should be avoided. If, however, the methods engineer has some data to guide him, he may under certain circumstances establish values without studies or formulas.

[1] Chap. XXXIII, "Time and Motion Study and Formulas for Wage Incentives," 2d ed., by Lowry, Maynard, and Stegemerten.

One method of doing this is to establish values by comparison. If, for example, values have been established by time study for machining rings *A* and *C* of Fig. 22, when ring *B* comes through the shop, it will be possible to establish a fairly accurate time by comparing its size with the size of rings *A* and *C* and arriving at a time that falls between the values for *A* and *C* in magnitude. The danger of the comparison method is that in rush periods there is a temptation to establish values by comparing jobs which are not comparable. This, of course, robs the results of what little accuracy the comparison method, properly used, possesses.

When estimates must be made, the more data that are available, the more accurate are the estimates likely to be. Experience and judgment alone are insufficient. Within a line of work, it is sometimes possible to compile rough data based upon units that are common to all jobs. One of the most common examples of this is the use of casting weights to determine time allowances or costs. Data that consider weight only are certain to give inaccurate results, however, since the time for the operation will be influenced by such factors as kind and number of cores required, whether molding is done on bench, machine, or floor, size and shape of casting, and a dozen other factors.

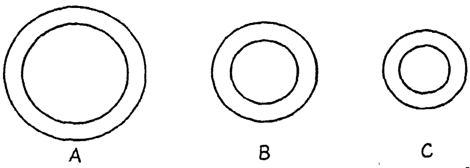


FIG. 22.—Similar rings to be machined—time allowances established by time study for rings *A* and *C*. Time allowance for ring *B* may be determined by comparison.

In spite of this, the per pound basis is a favorite way for estimating not only the cost of raw castings but also the cost of such complicated apparatus as turbines, motors, condensers, and the like. Estimates made in this way are averages and are likely to be inconsistent on individual jobs. They are used principally because results are obtained quickly.

When a per pound basis is used for estimating, accuracy is increased if the work is broken down into a number of classifications. For gray-iron castings, for example, a set of data that would give fairly accurate results could be set up as follows.

Benchwork only				Flask size up to 18 by 14 by 4/4 in.														
Weight, lb.	Without cores			With cores														
	Chunky	Medium	Spread out	One			Two			Three			Four			Five		
				C	M	S	C	M	S	C	M	S	C	M	S	C	M	S
Up to 1......																		
1 to 5........																		
5 to 10.......																		
10 to 20......																		
20 to 50......																		
50 to 100.....																		
100 to 200....																		
Over 200.....																		

On light assembly work, the number of bolts including nuts and washers might be used as the unit for estimating. On switchboards, it might be the number of wiring points, or a value might be established for each class of relay, circuit breaker, meter, switch, and so on. In any event, the data should be based upon accurate time studies if they are to give usable results.

The application of most forms of standard data is quick, but the results obtained are not likely to be satisfactory. Allowances established from inadequate data are usually inaccurate, and difficulties are experienced in applying them which are avoided where allowances are established accurately. The reason that this type of study is mentioned at all is that it is quick and hence may have an application on jobbing work where quantities are unusually small.

Because any sort of standard data is quickly and easily applied, it is sometimes used even though another type of study would be much more profitable. Thus, in small plants and even in some that are not so small, the estimator with his estimated allowances is sometimes found, merely because it appears easier to continue with this procedure than to make the necessary effort to understand and introduce the more exact and more profitable procedures.

Even on jobbing work, it is doubtful if the type F study is often justified. In a certain plant manufacturing an engineering product to customers' specifications, the average lot size was three pieces. With such small quantities, it was for a long time thought

to be impractical to set time allowances other than by estimate. Detailed time study was out of the question. It would require a time-study man for every operator. The only alternative to estimating lay in the derivation of time formulas. Even this seemed of doubtful practicality at first; for although it was no great problem to make type E studies and derive time formulas that would give accurate time allowances, experience with previously constructed formulas indicated that even this device would require too much time to apply. The problem was worked upon, however, and eventually improvements in the then existing formula procedure were developed until accurate formulas were derived that could be applied more rapidly than the estimator could work. It required slightly longer to work out the time allowance than to estimate it; but because the formula gave accurate results, the time previously spent by the estimator in discussing incorrectly estimated allowances with the worker and adjusting them was eliminated. The installation resulted in a better satisfied working force owing to the correctness of all time allowances and to more accurate costs, in the elimination of incorrectly high allowances, and in a smoother running shop.

In view of this and similar experiences, it seems safe to say that if the full time of but one man is occupied on a given class of work the type E study will usually prove profitable, even though the lot sizes are very small. Hence, the type F study is limited to small-quantity, part-time operations. In general, the best results are secured when the studies, of whatever the type, are made by thoroughly trained engineers.

CHAPTER V

FIELD OF APPLICATION OF SIX TYPES OF METHODS STUDY

The type of methods study that may economically be employed on any job or class of work depends upon individual conditions. Since an infinite variety of conditions is encountered in industry, it is necessary to determine the principal factors that influence the choice of a given type of study and to set up a procedure that, although admittedly empirical in nature, will permit the quick selection of the proper type of study under any set of conditions with a reasonable amount of accuracy.

The kind and the amount of study that are economically justified on any job or class of work are determined by three principal factors, namely, the repetitiveness of the job, the labor content, and the expected life of the job. All these factors must be considered together, for no one of them in itself is sufficient.

Repetitiveness.—The repetitiveness of an operation cycle is determined in part by the number of times the cycle is repeated in exactly the same way. On the majority of jobs, the number of repetitions of the operation cycle and the number of parts produced are the same, for the operation cycle is repeated once for each part produced. There are numerous important exceptions to this rule, however. It is possible that a job calling for 2,000 pieces might be less repetitive than a 1-piece job.

For example, the assembly of 2,000 relay panels would be a highly repetitive job. The same cycle of operations is performed on each part produced, and 2,000 repetitions is sufficient on this particular job to place it in the highly repetitive class. On the other hand, a job calling for 2,000 punched parts that are made in a 10-cavity die would not be a highly repetitive job. The operation cycle would be repeated only 200 times to produce 2,000 pieces.

The blading of a large steam-turbine spindle presents just the opposite condition. Only one complete spindle is produced; but

since the design of the turbine may be such that a number of identical rows of approximately 200 blades each are used, the installing of the blading is a repetitive operation, even though but one spindle is involved.

In determining whether or not an operation cycle is repetitive, the length of the cycle must also be considered. A job with a yearly activity of 50,000 pieces might or might not be considered a highly repetitive job. If the length of the operation cycle were 0.200 hour or 12 minutes, the total length of the job would be 10,000 hours. Thus, five operators working 2,000 hours per year would be required. This, then, would be a highly repetitive job and would justify intensive methods study. On the other hand, if the job were a simple, rapid punching operation and the time allowance per piece were 0.0006 hour, the entire job would last only 30 hours, and it would be considered to be of low activity.

For the purpose of determining the field of application of the six types of methods study, the repetitiveness of the operation cycle may be divided into four classes: high, medium, low, and jobbing. The following general definitions will serve as a guide in fixing the repetitiveness of any job.

High—A job may be considered highly repetitive if it consists of not less than 2,000 pieces per year and requires not less than 1,000 hours to complete.

Medium—A job may be said to be medium repetitive if it has not less than 500 pieces per year and lasts 1 to 6 months.

Low—A job of low repetitiveness may consist of not less than 50 pieces per year and may last from 2 weeks to 1 month.

Jobbing—A job of under 50 pieces or lasting less than 2 weeks and not repeating will be considered as falling in the jobbing classification.

Judgment must be used in applying these definitions. There are special cases that may not fit the definitions exactly, but the definitions will nevertheless act as a guide. The remarks which were made in Chap. III regarding the repetitiveness of individual elements in certain classes of work should be reviewed in this connection.

Labor Content.—The portion of the operation cycle that is performed by human labor has an important bearing upon the type of study that it is profitable to make. Tacks, for example,

are made in large quantities, and the more popular kinds will fit the definition of highly repetitive work. The type A methods study would not be justified, however, for the labor content is low. Tacks are made by automatic machines, and the only labor involved is that of an operator who watches a battery of machines to make sure that everything is going properly. His motions are nonrepetitive, and a detailed motion study would be pointless.

The labor content of an operation may for convenience be classified as high, medium, and low. The maximum condition, of course, is when all work is performed by human labor, and the minimum is when the job is done automatically by machinery. The class into which any job falls with respect to labor content may be determined as follows.

High—over 75 per cent human labor.

Medium—25 to 75 per cent human labor.

Low—under 25 per cent human labor.

Again, the limits established are arbitrary, and judgment should be used in applying them.

Life of Job.—The life of a job must be considered as well as repetitiveness and labor content; for the more detailed types of study require considerable time to make, and it must be determined whether or not the job will last long enough after it has been improved to return the expenditure required to improve it.

Ordinarily, a job of 100,000 pieces on which the labor content was high and the length of operation cycle was 0.0200 hour would justify detailed study. Work to the amount of 2,000 hours is involved, and this is sufficient to offer attractive savings if the usual improvements that result from careful methods study are obtained. A detailed study might require 2 to 4 weeks, however, and if the job had to be completed within a month it would be finished before the results of the study could be applied.

Such conditions exist, for example, in the field of the manufacture of novelty articles. Quantities are large, and the labor content of the operations is often high; but because the product is strictly a novelty, the life of the job is short. Here, the problem is one of getting the method developed quickly and then of training a number of operators to follow it, so that the product may be turned out in large quantities while it is in demand. Time does not permit the development of refined methods, and careful operator training is out of the question. If the product

is to be made at all, it must be made immediately. Seasonal industries face the same problems, although if the operations remain the same or nearly the same from year to year detailed study may be justified.

The length of life of the job will be divided into three classes as follows:

Over 12 months.

6 to 12 months.

Under 6 months.

These classes need no explanation.

Determination of Field of Application of Six Types of Methods Study.—With the factors that determine the field of application of the various types of method study determined and classified, a tabulation may be made which will serve as a guide in determining the type of study economically justified under any given set of conditions. This tabulation is as shown on page 67.

This tabulation is based upon the average conditions encountered in industry, but it is a reasonably accurate guide to follow in mapping out a methods-engineering program or study procedure. Where a choice of two or more types of study is indicated, the particular conditions surrounding the job will determine which type is best.

Using the Table.—The most difficult factor to determine when using the table is the repetitiveness of the job. The labor content and the expected life of the job may be quickly checked; but because repetitiveness in the sense in which it is used here is affected by the number of pieces per year, the length of the operation cycle, and the total length of the job, more detailed consideration must be given to this factor.

As previously defined, a job may be considered to be highly repetitive if it consists of not less than 2,000 pieces and requires not less than 1,000 hours to complete. To express this algebraically, if the formula

$$\frac{N \times TA}{1{,}000}$$

where N = number of pieces not less than 2,000,

TA = time allowed

gives a value of 1 or greater, the job may be classed as highly repetitive. The value of N = not less than 2,000 pieces is an

arbitrary figure and may be varied to suit individual conditions. The formula takes into account all the variables that must be considered, however, and hence offers a valuable guide.

Repetitiveness of operation cycle	Labor content	Life of job	Type of study indicated
High	High	Over 12 months	A
		6 to 12 months	A or B
		Under 6 months	B or C
	Medium	Over 12 months	A or B
		6 to 12 months	B or C
		Under 6 months	C
	Low	Over 12 months	B
		6 to 12 months	B or C
		Under 6 months	C
Medium	High	Over 12 months	B
		6 to 12 months	B or C
		Under 6 months	C
	Medium	Over 12 months	B or C
		6 to 12 months	C
		Under 6 months	C or D
	Low	Over 12 months	C or E
		6 to 12 months	C, E, or F
		Under 6 months	F
Low	High	Over 12 months	C or D
		6 to 12 months	C, D, or E
		Under 6 months	C or E
	Medium	Over 12 months	C, D, or E
		6 to 12 months	C or E
		Under 6 months	C, E, or F
	Low	Over 12 months	C or E
		6 to 12 months	C, E, or F
		Under 6 months	F
Jobbing	High	Under 6 months	E
	Medium	Under 6 months	E or F
	Low	Under 6 months	F

A job by definition is medium repetitive if it has not less than 500 pieces per year and lasts 1 to 6 months. To be considered medium active, therefore, the following formula must give a value of 1 or greater:

$$\frac{N_1 \times TA}{167}$$

where N_1 = not less than 500.

A job of low repetitiveness consists of not less than 50 pieces per year and lasts 2 weeks to 1 month. The formula is

$$\frac{N_2 \times TA}{80}$$

where N_2 = not less than 50.

If applied with judgment, these formulas will assist in determining the repetitiveness of a job.

The use of the formulas and the table may be illustrated by several examples. In a machine shop doing miscellaneous work, several representative jobs are selected to test the type of methods study that it is economical to make. On the first job considered, the activity is estimated to be 5,000 pieces per year. The first operation is a lathe operation that requires 0.392 hour to perform. This figure may be estimated or determined by time study, or it may be a time allowance already in effect. Substituting in the formula

$$\frac{N \times TA}{1{,}000}$$

gives a value of 1.96. This operation, therefore, would be classed as highly repetitive.

Several long cuts are involved on the operation during which the machine has complete control of the operation. The labor content of the job is therefore estimated to be 45 per cent and hence is classed as medium. The job is a standard job made year after year. Therefore, the life of the job is over 12 months. If the table on page 67 is referred to, it is found that a repetitive job of medium labor content lasting over 12 months calls for a type A or B study. In this particular case, because the labor content is rather low and the possibilities for improvement through detailed motion study appear limited, the type B study would be chosen.

The second operation consists of drilling and tapping two holes. The time allowance is 0.15 hour. Substituting in the same formula as above gives a value of 0.75. Since this is less than 1, the operation would not be considered highly repetitive. Therefore, the next formula is tried, that is,

$$\frac{N_1 \times TA}{167}$$

This formula gives a value of 4.5, and so this operation will be classed as medium repetitive.

The entire operation is under control of the operator; so the labor content is 100 per cent, or high. The length of life of the job is, of course, the same as for the first operation. If the table is referred to again, it is found that a type B study is indicated.

All the operations on this and the other representative jobs are similarly tested. As a result, the predominating type of study that is justified will be readily determined.

A shoe factory is engaged in making two general types of women's shoes, dark shoes for fall and winter and white shoes for summer. At the start of the summer style season, which lasts approximately 6 months, the new styles are introduced into the plant. A certain style is selected for testing. It has an estimated activity of 100,000 pairs or 200,000 shoes.

The operation of "trim lift on heel" is selected for test. The allowed time is 0.0009 hour per heel. Since the same heel is used on the right and the left shoe, the activity is 200,000. Substituting in the formula

$$\frac{N \times TA}{1,000}$$

gives a value of 0.18. If this operation were done only on the heel being tested, the operation would not be considered highly repetitive. Instead, by substituting in the next formula, it would be found to be medium repetitive.

As a matter of fact, however, the operation "trim lift on heel" is performed on every heel made. Assuming a yearly production of 2,000,000 pairs or 4,000,000 heels, the activity would then be classed as high. Since the labor content is 100 per cent, a type A study would be indicated.

When the season has but 3 months to run, a new sandal is put into production in response to popular demand. It is of unusual design and requires a special assembly operation estimated to take 0.0075 hour per shoe which no other shoe requires. The sales department estimates that it will sell 150,000 pairs of this sandal.

To determine the type of study justified, the repetitiveness is first tested as before. Substitution on the first formula gives a value of 2.25. The job is therefore highly repetitive. Labor content is 100 per cent, and the life of the job is under 6 months.

For these conditions, a type B or C study is specified by the table. In this case, because the activity is rather high, the type B study could be chosen.

Before reaching a definite decision, the stylist of the company should be questioned as to the possibility of the same or a similar sandal being made during the next season. If it is learned that there is a good possibility that a very similar sandal will be made in large quantities a year hence, then in all probability a type A study would be worth making.

These few examples will serve to indicate how the formulas and the table plus a liberal amount of judgment are used to determine the type of study that is economically justified by any given set of conditions. If the review of a number of representative operations shows that a type A or a type D study is desirable, the plant will be justified in purchasing motion-picture equipment and conducting intensive methods studies. If the majority of jobs indicate a type C study, then a less detailed program will be mapped out.

CHAPTER VI

PROCESS CHARTS

The next chapters deal with specific methods of making operation analyses with the aid of various types of process chart and a form known as the "analysis sheet." It will be assumed in all cases that a preliminary investigation of the repetitiveness, labor content, and life of the job has been made and that the particular form of detailed analysis being described is justified. Hence, instead of continually qualifying the description of a detailed procedure with such phrases as "if the activity of the job warrants it," it will be assumed that the reader now understands to what type of work the procedure applies. When all the analysis techniques available to the methods engineer are clearly understood, it is a simple matter to discard those that are not economically justified in any individual study.

Process Charts.—A process chart may be broadly defined as any charted presentation of information connected with a manufacturing process.

This is a very general definition and indicates that there can be, and are, many different kinds of process chart. Indeed, it is hardly general enough; for there are process charts that are more in tabulated than in chart form, and process charts may be used to present information about processes that are not connected with manufacturing such as the movement of transportation units for public carriers, the course of a sales order through a sales organization, or the process by which long-distance communication is handled.

Process charts, however, were originally designed by Frank B. Gilbreth for industrial use and are used most extensively at the present time in manufacturing industries. The information that is presented by process charts can include any or all of such factors as distance moved, operations performed, motions used, working and idle time, cost, production data, time allowances, and other similar data.

Use of Process Charts.—The process chart forms a convenient means of presenting in a limited space information about an operation or process. It can be used to show the relation among operations, the steps of a process, or several sets of data. It permits the quick visualization of a problem so that improvement can be undertaken systematically and in logical sequence.

It should be clearly understood that the process chart is not a wonder-working device which of itself will lead to operating economies. Rather, it is a means of preparing data for study so that those who are making the study can grasp the problem at a glance and proceed toward its solution without delay or wasted effort. Often, when process charts are prepared, the inefficiencies in the process become so apparent that it is difficult to see how they could have been overlooked before.

Probably, most methods engineers who have committed to paper data gathered during the course of a job analysis have prepared a kind of process chart whether they called it by that name or not. The process chart is a valuable tool of the methods engineer and one for which he finds frequent use, particularly if he must present his data to others. Although the drawing of a process chart assists in organizing data, it is possible that an individual engineer can carry his data mentally and arrive at some worth-while results. If, however, he must present his data to others in order to sell an idea or to obtain authorization to make certain changes, he will find the process chart form of presentation invaluable. It shows up facts so clearly that action results.

In this connection, the story has often been told of the time that Frank Gilbreth approached the chief executive of a manufacturing concern and spread out a long process chart on his desk. The executive with scarcely a glance at it said, "I can tell you right now that I won't approve it, whatever it is. It's entirely too complicated." "You're right," said Gilbreth quietly, "but this happens to be a process chart of your present procedure." The chart showed this executive more at a glance than he could have gathered from several hours of discussion.

When a group is formed for the purpose of studying and trying to improve a given job, process charts are practically indispensable. Whenever several men are to work together toward a given end, it is necessary that they start from the same point

and proceed in the same direction. In order to do this, they must have a clear understanding of the problem as a whole. Otherwise, one may start to consider the beginning of the process, another the middle, and a third the end. Each will offer suggestions, and these suggestions may conflict. Usually, the suggestion that is presented most forcibly will be considered first whether the point involved should come first or not. The resulting discussion is uncoordinated, involved, and often discordant. The progress of the group is correspondingly slow.

If, however, a process chart is first prepared and every member of the group is given a copy to study, the discussion will start

FIG. 23.—Process charts are indispensable for group methods studies.

at the beginning and proceed systematically toward the end. Progress is rapid, and little time is wasted by the discussion going off at a tangent.

The authors have had considerable experience in conducting group studies of operations, products, and processes. They find that after a given group has made a study or two the members themselves insist upon having process charts furnished at the beginning of each new study. They see very quickly what a time- and energy-saving device the charts can be.

Types of Process Chart.—The type of process chart that is prepared for any study depends entirely upon the job under consideration. There is no fixed form of process chart that is rigidly adhered to by all methods engineers, or even by any one engineer. The chart is varied to suit the nature of the study that is being made and the data that it is desired to present.

There are, however, certain major types of chart that, with minor variations to cover specific conditions, are widely used for

methods-study work. These are six in number and may be listed as follows:

1. Operation process charts.
2. Flow process charts.
3. Man and machine process charts.
4. Operator process charts.
5. Progress process charts.
6. Miscellaneous types.

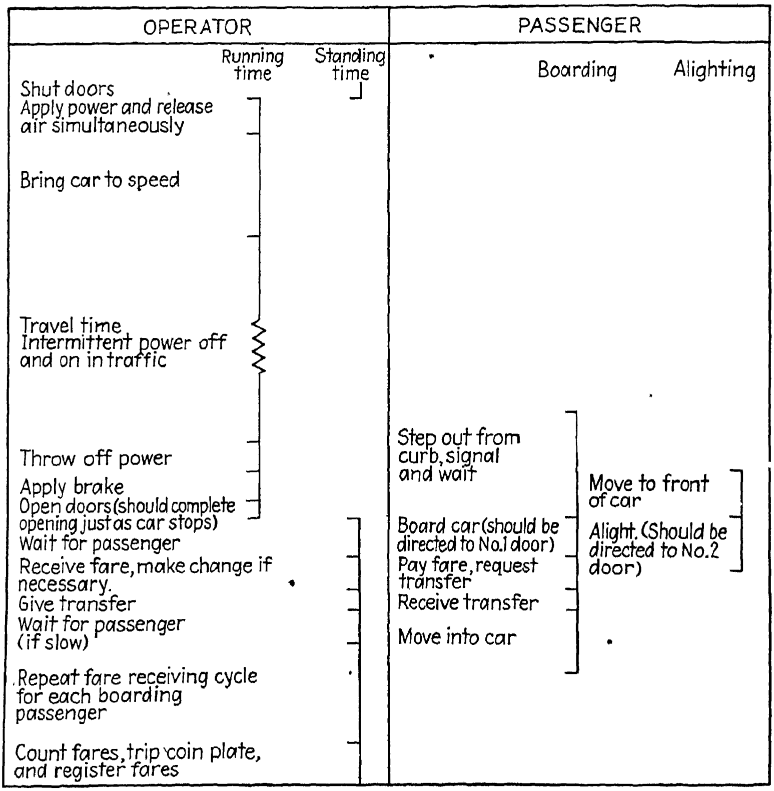


FIG. 24.—Process chart of one-man streetcar operation—pay enter.

The operation, flow, man and machine, and progress types of process chart will each be discussed in a separate chapter as they are used primarily in making detailed job analyses. The operator process chart, examples of which have already been given in

Figs. 10 and 13 of Chap. IV, will not be described fully in this volume, as this type of chart belongs with a discussion of detailed motion study.

The miscellaneous types of process chart include all specially devised charts that are designed for a specific study and that cannot readily be classified under the first five headings.

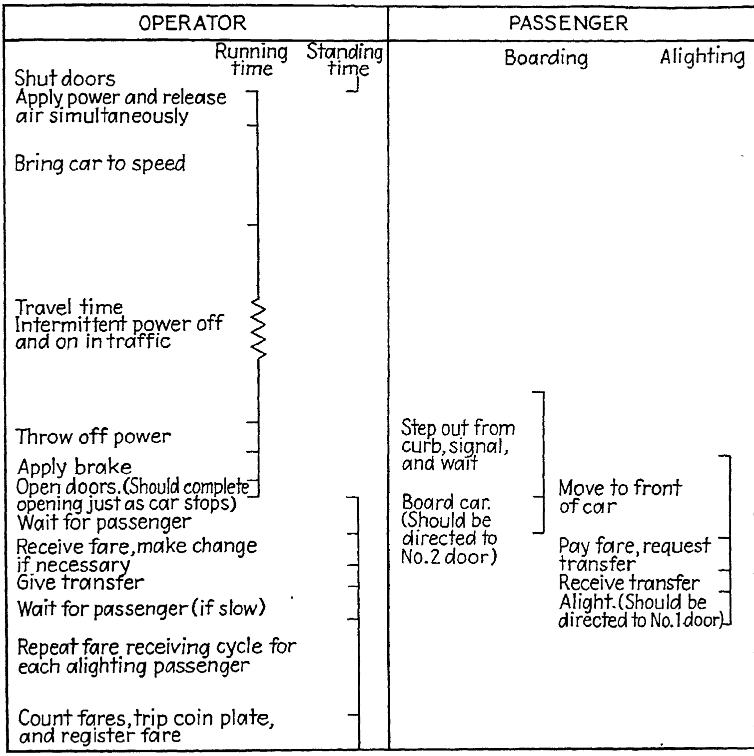


FIG. 25.—Process chart of one-man streetcar operation—pay leave.

For example, during the course of a certain group study, it was desired to show the operations performed by the operator of a one-man streetcar and also the operations performed by a passenger when boarding or leaving the car. It was important to show how these two sets of operations were related one to the other, for a search was being made for all factors that might

cause delay to operating schedules. Accordingly, the charts shown by Figs. 24 and 25 were devised to present the desired information.

Since the various miscellaneous types of process chart are used for special studies and hence are not of general interest, no further mention will be made of them.

CHAPTER VII

THE OPERATION PROCESS CHART

One of the first things that must be known when a study to improve a product or process is begun is the operations that are performed. Before a process can be improved, one must understand clearly what it is at the present time.

On a simple job like the producing of a lid for a cooking utensil from a sheet-metal stamping, the few operations required are comparatively easy to visualize in their proper sequence; but on an assembly this is not so easy even if the job is fairly simple. Whenever two or more parts requiring certain processing operations come together to make an assembly, not only must one know what operations are performed on each part and in what order but also one must be able to see what relation each operation bears to each preceding and succeeding operation and to the operations performed upon the other parts of the assembly. If one attempts to improve or change an operation without considering the effect of the change upon all the other operations, one is likely to make the job as a whole more complex rather than more simple.

The operation process chart is a valuable means of showing clearly the operations performed on a given product and permits a quick grasp of the various operations in their relation to one another.

Constructing the Operation Process Chart.—On the operation process chart are usually shown:

1. The operations.
2. The materials.
3. The time allowances.
4. The inspections.

Other information such as machine or work-station identification, male or female labor, pieces per hour, and the like, can be given if desired. The four items listed above are practically always required for any methods study and should always be recorded

upon the chart as a matter of standard practice. It is a simple matter to add other information to the chart if it is desired.

Operation process charts are drawn on plain paper of sufficient size to accommodate the information that must be recorded. The two standard symbols shown by Fig. 26 are used to denote operations and inspections. The symbols are useful for distinguishing at a glance between operations and inspections without the necessity of reading the detailed information given on the chart. The letters within the symbols help those who do not refer to process charts frequently to recognize what the symbols mean, and the numbers are useful both for showing the number of operations or inspections that are performed during the process and for reference purposes.

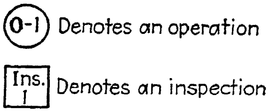


FIG. 26.—Standard symbols for operation process charts.

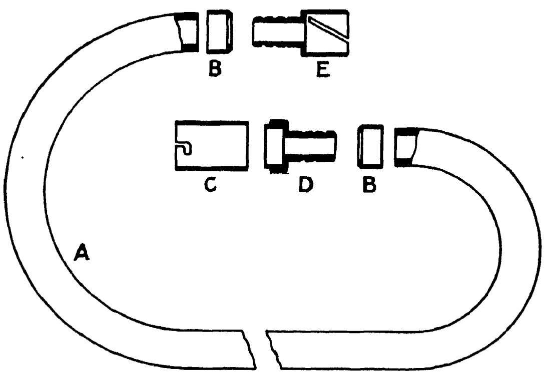


FIG. 27.—Parts for rubber supply hose.

The steps in the construction of an operation process chart may best be described by taking a fairly simple product and working up a chart for it. For this purpose, a rubber supply hose with connections has been chosen. The hose is made up of a piece of rubber tubing 6 feet long, two purchased ferrules, and three machined parts. These parts are shown in Fig. 27. *A* is the rubber hose, *B* the ferrules, *C* a bayonet made from brass tubing, and *D* and *E* inserts machined from brass rod. To make the final assembly, parts *C* and *D* are soldered together and with a nickel-plated ferrule are assembled to one end of the hose.

Insert *E* and a ferrule are assembled to the other end. The completed job furnishes a flexible connection between two parts of a certain medical apparatus.

In constructing an operation process chart, the first step is to select the major item of the assembly. The operations performed on this part are charted first; and as the other parts join the major part, they in turn are charted. In this case, the rubber hose would be chosen. Either of the inserts could have been chosen; but since they both come together for assembly to the rubber hose, the chart will have a more pleasing appearance if the hose is used as the starting point.

The chart is started at the upper right-hand corner of the paper. The material required for the first operation is noted

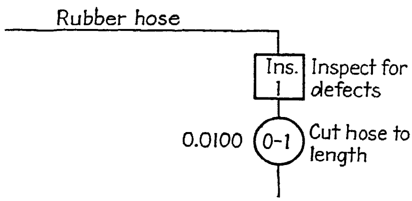


FIG. 28.—First steps of operation process chart construction for rubber supply hose.

first. This may be purchased material or material supplied by another department whose operations and processes it is not desired to study. Usually, for the sake of completeness and to insure that no possibility for improvement is overlooked, it is best to include all operations performed in the plant on the operation process chart. Vertical lines are used to represent the general flow of the process and horizontal lines to represent material feeding into the process.

In the case of the rubber hose, the material is purchased in long lengths. It is first inspected for defects in the receiving department and is then cut to length in the rubber department. This is represented on the chart as shown in Fig. 28. First, the material is shown. This is "rubber hose." It is represented as feeding into the process by a horizontal line drawn directly below the words "rubber hose." The horizontal material line then joins the vertical flow line of the process. Following down the vertical line, the first inspection is charted. A square is drawn, and in it is written "INS-1." A description of the work,

"inspect for defects," is also recorded. The next thing that happens to the hose—aside from transportation and temporary storages which are not shown on an operation process chart—is the operation "cut hose to length." The operation symbol is drawn and "O-1" written inside it. The description of the operation, "cut hose to length," is recorded to the right of the symbol and the time allowed for the operation, 0.0100 hour, to the left.

The next operation performed on the rubber hose consists of assembling the insert *D* to which is soldered part *C*. Hence,

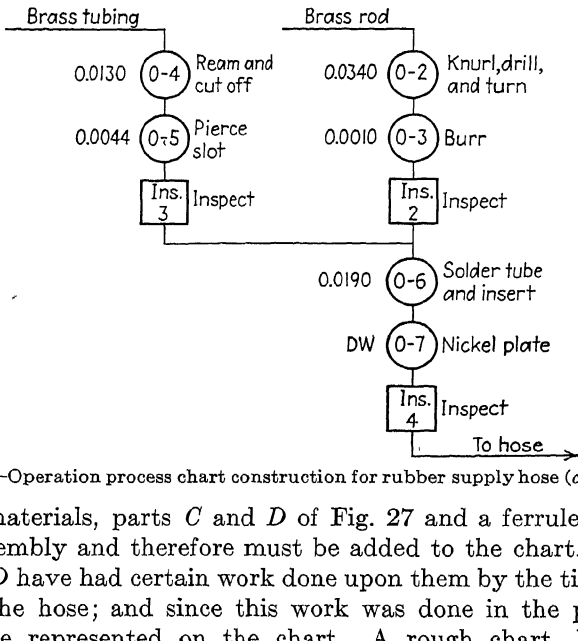


FIG. 29.—Operation process chart construction for rubber supply hose (*continued*).

more materials, parts *C* and *D* of Fig. 27 and a ferrule *B*, join the assembly and therefore must be added to the chart. Parts *C* and *D* have had certain work done upon them by the time they reach the hose; and since this work was done in the plant, it must be represented on the chart. A rough chart, Fig. 29, is first prepared to show what the work was. Since the insert is the major part, a start is made with it. The material, brass rod, is shown first. An operation symbol is next drawn in the vertical flow line. The operation description and the allowed time are recorded; and the next unused operation number is inserted in the operation symbol, in this case, "O-2." The following operation is charted in the same way, as is the next inspection which is assigned the number 2.

After inspection, the next operation is to solder tube and insert together. Here, the tube joins the insert; and since it has had previous work done upon it, these operations must be charted. The procedure followed is exactly the same as before. The purchased material is shown first. The first operation is described; and the next unused operation number, "O-4," is recorded inside the symbol. The second operation and the following inspection are next charted. The part is then ready to join the insert. Hence, a horizontal line is drawn showing the part feeding into the insert's flow line at the proper point.

The course of the parts is now charted together. The operation that brings them together, "solder tube and insert," is charted as before and is assigned the next unused number which is "O-6." The nickel-plating of the assembly and the inspection that follows are then shown. The part is at length ready to join the hose. Hence, a return is made to the chart previously started. The information from the rough chart is copied neatly, and the insert with bayonet connection attached is shown joining the rubber hose.

The same procedure is repeated until the final chart shown by Fig. 30 has been prepared. In its finished form, the chart shows clearly all the operations performed in the manufacture of the rubber supply hose. The operations are shown in their relation to one another, and a clear picture is given of the manufacturing process.

If an operation process chart is drawn up as the first step of a methods study, it insures that the study will begin at the right point which is the first operation and proceed systematically to the last operation. Without a chart, the study is quite likely to begin at the point that seems most obviously inefficient, for there is always a tendency to wish first to correct the points that are glaringly bad. To do so, however, may be a waste of time. For example, a group of interested supervisors was formed to study a certain process. In making a preliminary survey of the job, it was seen at once that one of the operations, "insert tube in paper container," could readily be improved. It was a typical "one-handed operation"; that is, one hand was either idle or holding throughout the operation. The natural tendency of the group that was studying the job was to wish to start with this operation. An operation process chart, however, showed

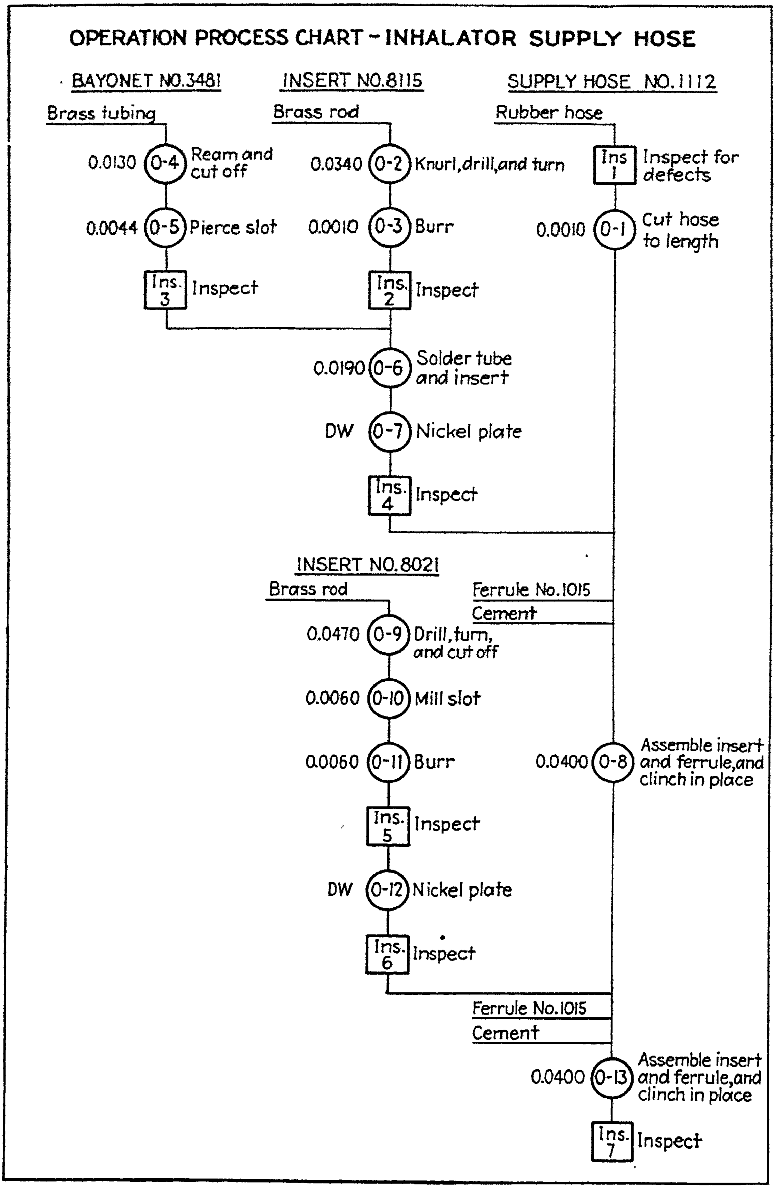


FIG. 30.—Completed operation process chart for rubber supply hose.

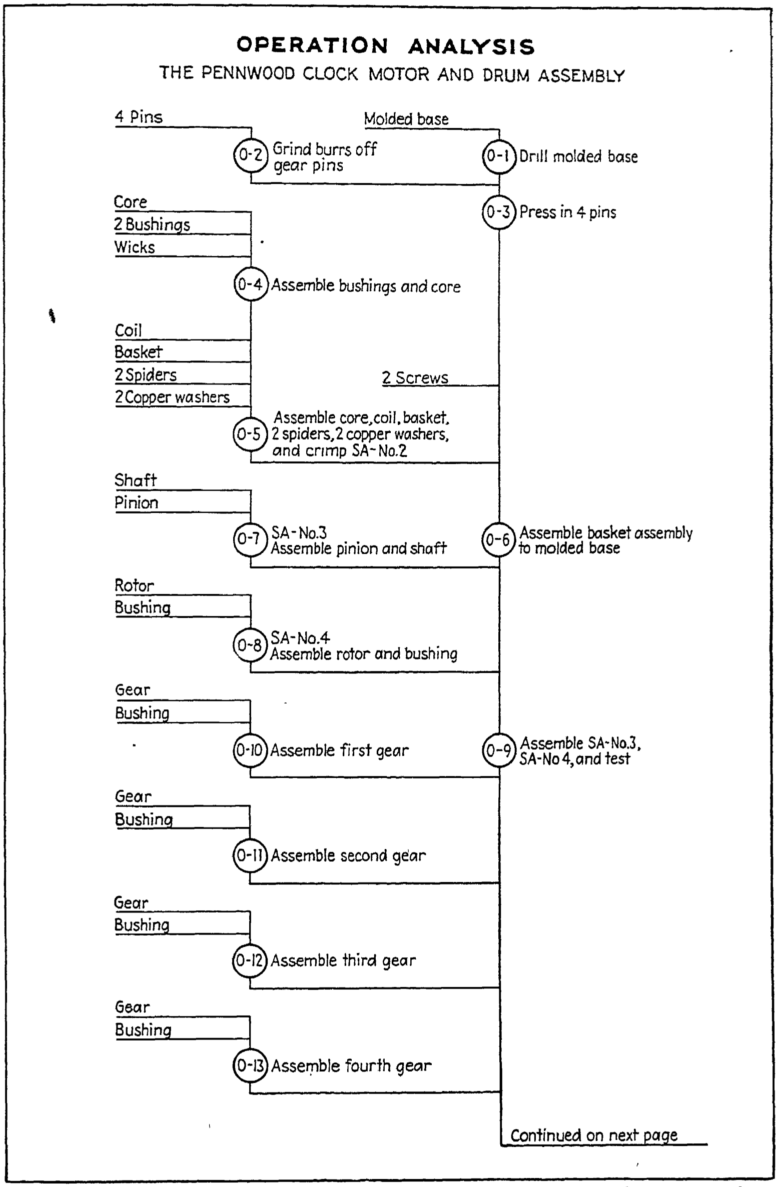


FIG. 31.—Operation process chart for electric clock motor and drum assembly.

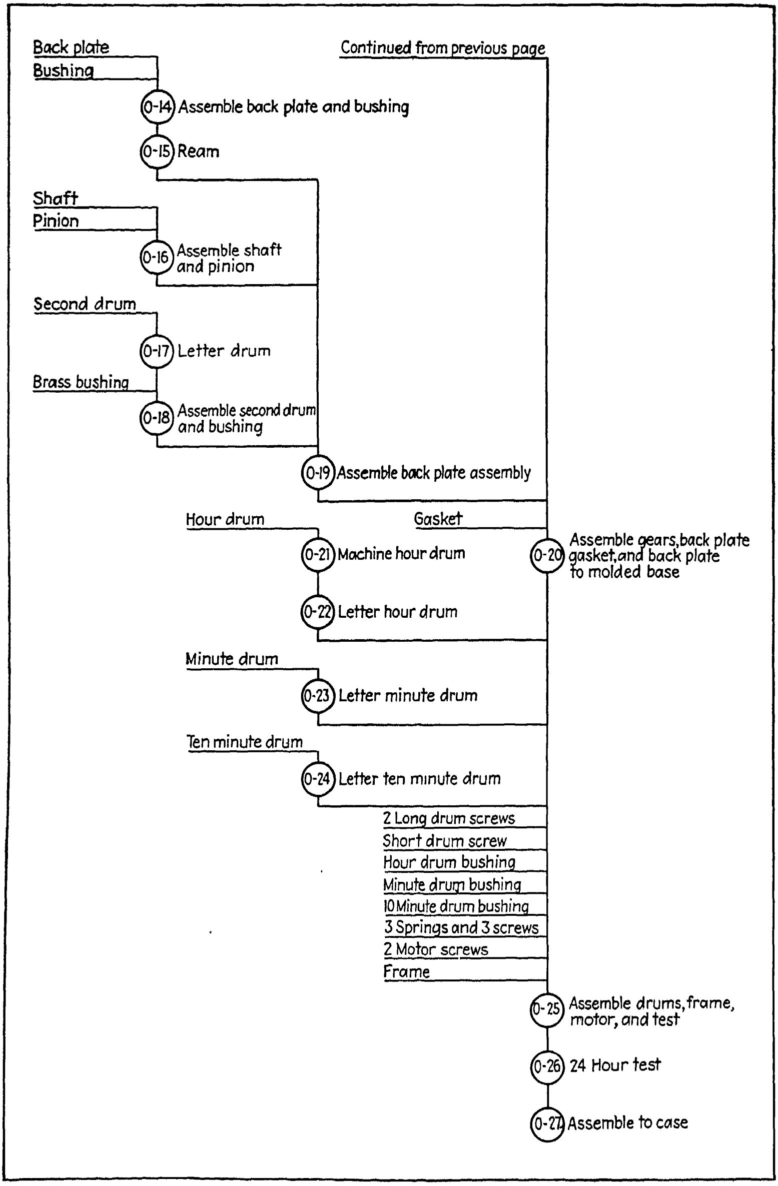


FIG. 31.—For descriptive legend see p. 83.

that this was not the place to begin; and therefore the preceding operations were studied first. As a result of this study, improvements were made that were so important that the assembly problem changed entirely. Had any study been given to the assembly operation previously, the work would have been entirely wasted.

Typical Operation Process Charts.—The operation process chart just described covers a comparatively simple product. Nevertheless, its construction was justified by the clear understanding it gave of the operations used to produce the hose. For more complicated assemblies, particularly in plants where the work is not well organized, operation process charts are an absolute necessity.

For example, a certain company was engaged in the manufacture of electric clocks. These clocks operated on a different principle from the conventional type of clock; and since they were a new product, considerable development was necessary. Operations were added and eliminated during this development stage until even those directly supervising the work hardly knew what operations were being performed or why.

When the process was at length considered to be fairly well developed, a methods engineer was engaged to study the operations and make improvements. Since little attention had been given to methods before, there were many obvious inefficiencies to be corrected. Before any detailed work was done, however, it was necessary to obtain a complete understanding of the then existing operations. To this end, the operation process chart shown by Fig. 31 was constructed.

A glance at this chart will show that it was constructed in accordance with the principles enumerated above. The motor base was chosen as the principal part, and the operations performed on it were charted first. As other parts joined the motor base, the operations performed upon them were traced back. Some of the parts in the subassemblies were also previously processed so that they too had to be traced back.

The completed chart shows just how the motor and drum assembly of the clock was being made, and it furnished a valuable guide for the methods studies which were subsequently made.

Figure 32 shows an even more comprehensive operation process chart which was prepared for a group that was about to

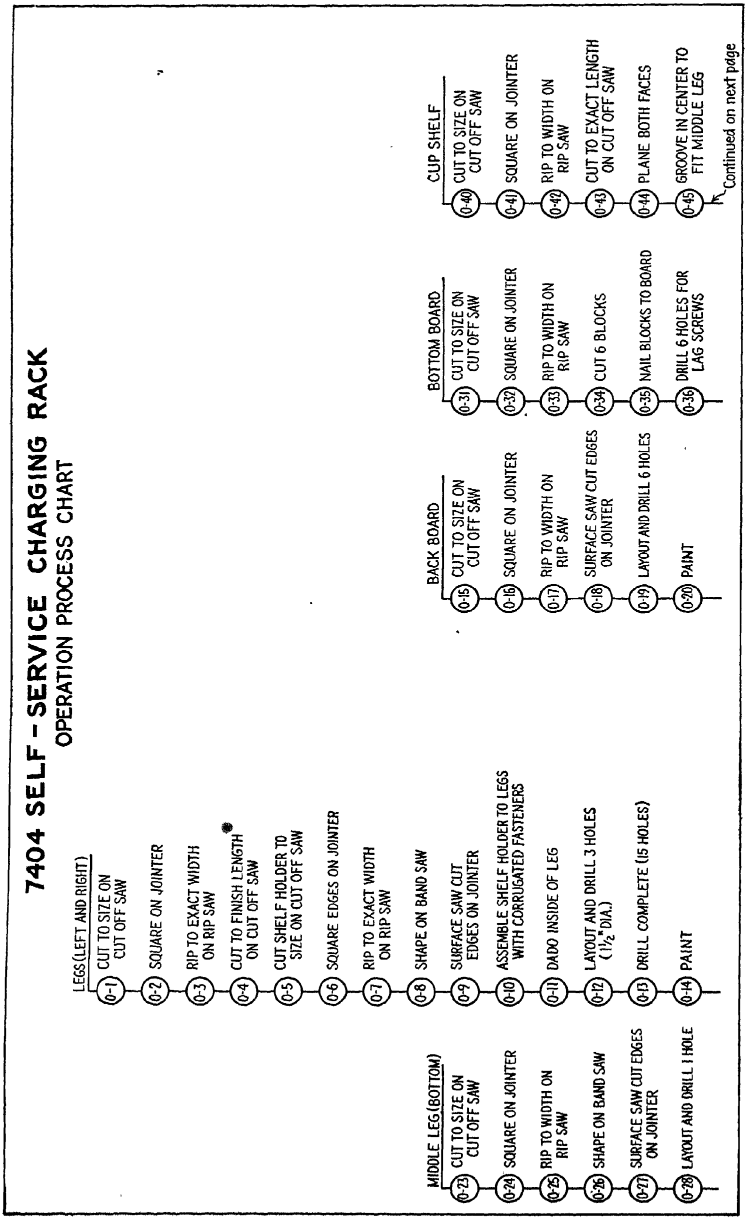


FIG. 32.—Operation process chart for self-service charging-rack assembly.

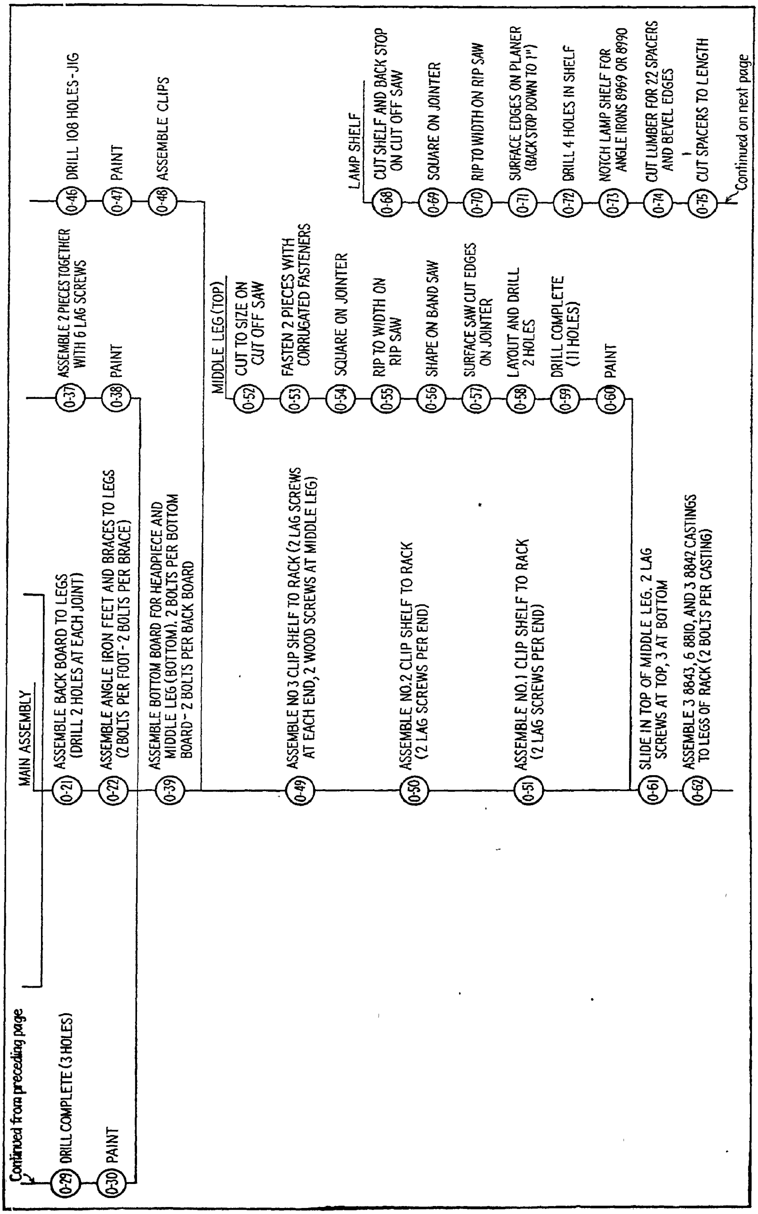


Fig. 32.—For descriptive legend see p. 86.

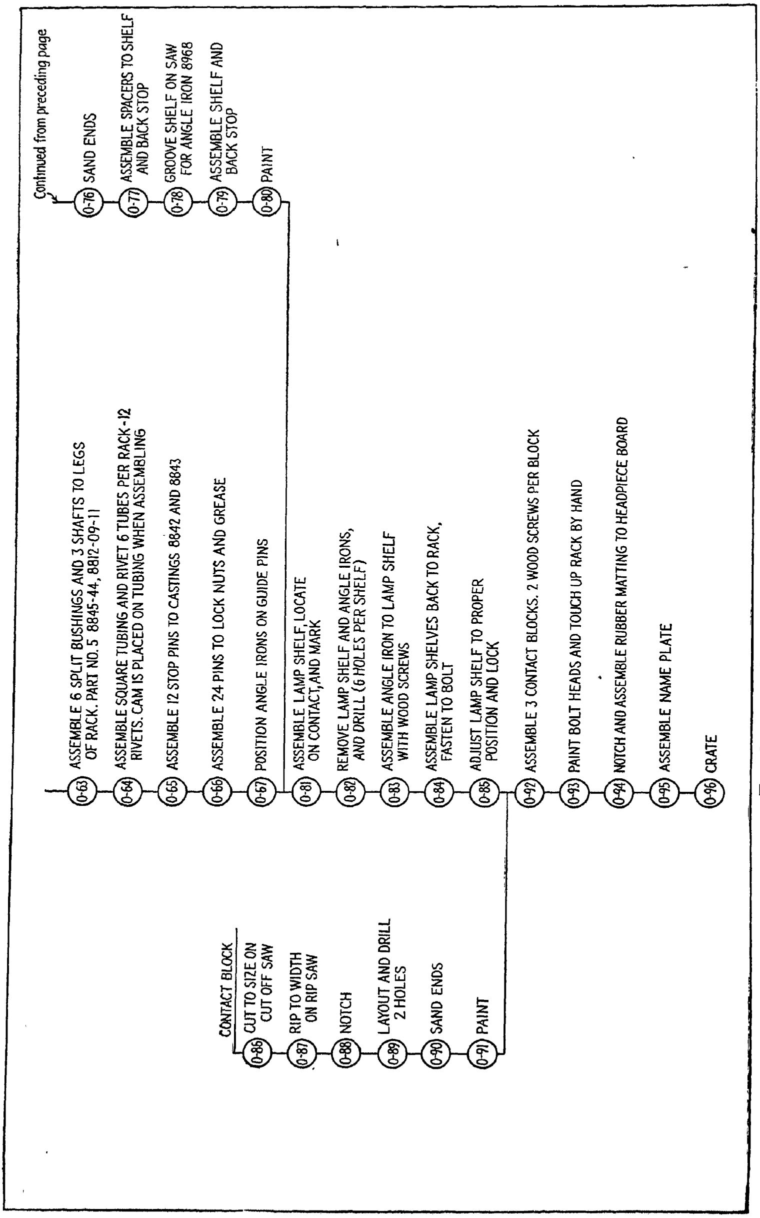


FIG. 32.—For descriptive legend see p. 86.

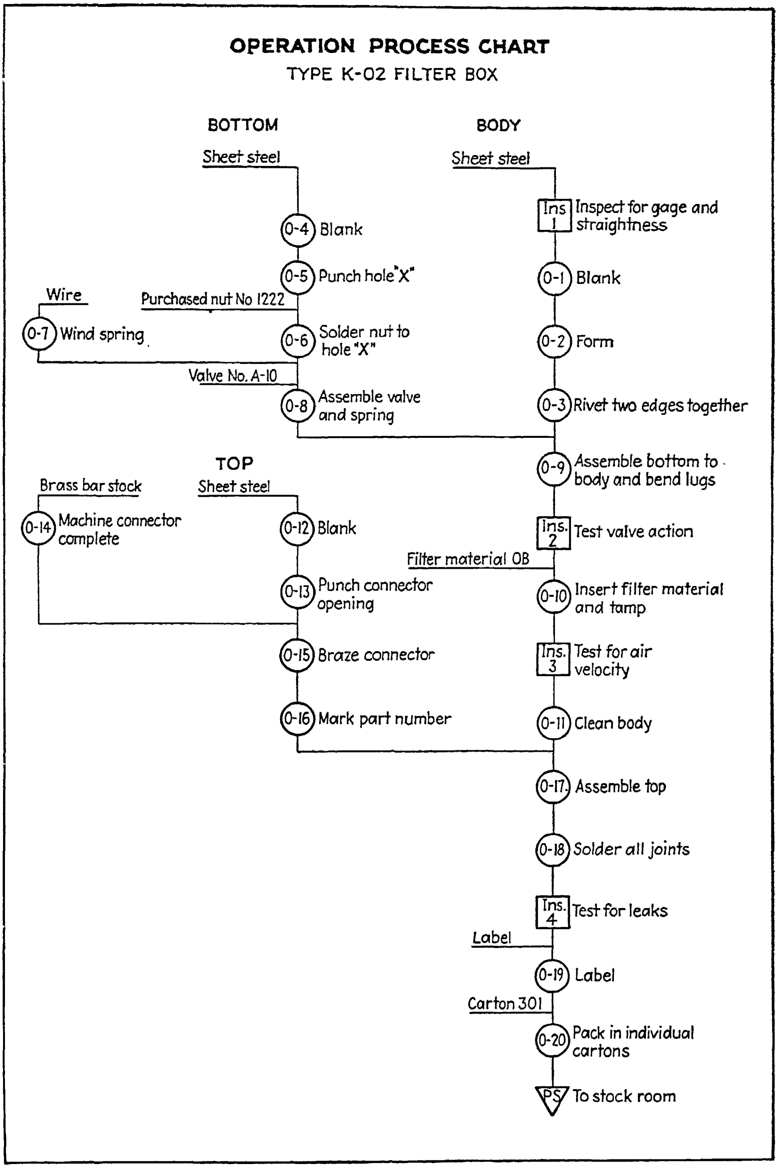


FIG. 33.—Operation process chart for type K-02 filter box.

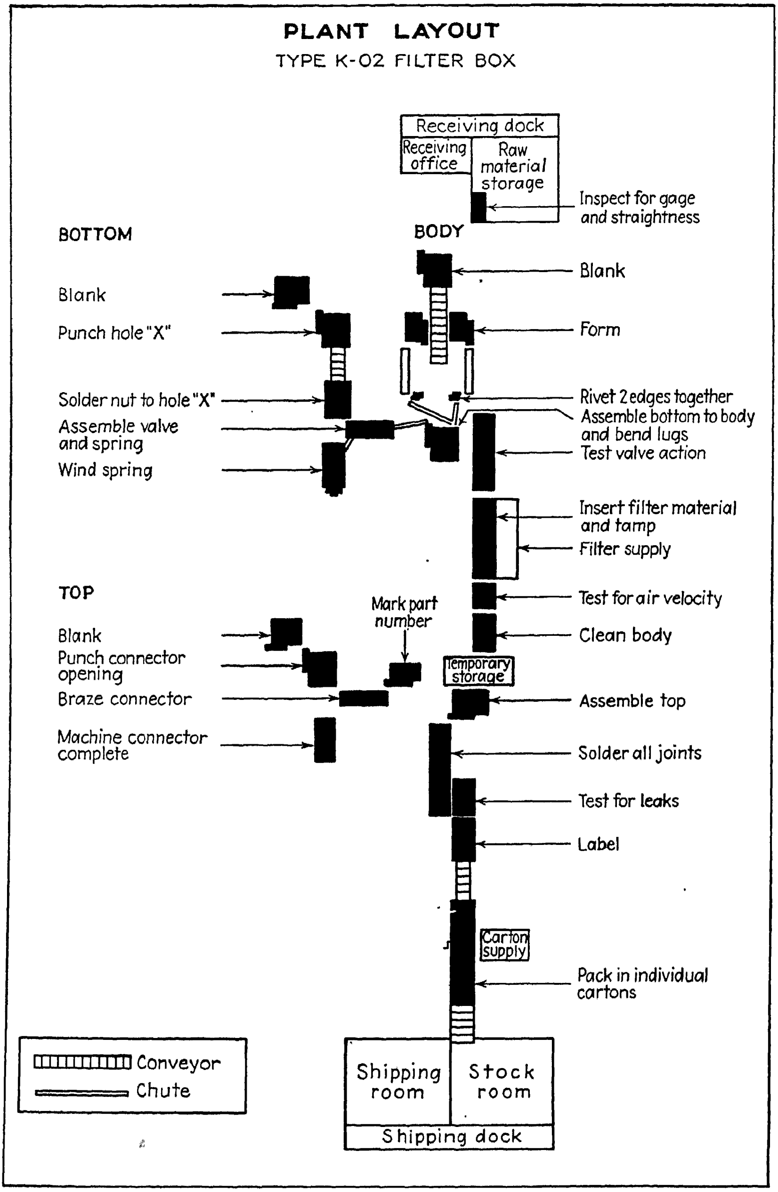


FIG. 34.—Plant layout for manufacture of type K-02 filter box.

take up the study of the operations performed in the building of a self-servicing charging rack for storage batteries. It can readily be appreciated that without this chart the group would have been at a loss as to where to begin its study or would have been unable even to understand the operations that were performed in its manufacture without many hours of detailed probing.

The Operation Process Chart as a Layout Aid.—When an assembly requires a large number of detailed operations and involves enough bulk to present a handling problem, it is important to lay out the workplace so that material flows properly through the operations with a minimum of handling. The operation process chart is an exceedingly valuable tool in this connection. When it has been drawn, it indicates on the most casual inspection the general form the layout should take, and makes simple what otherwise might be a complicated problem.

For example, if the largest or bulkiest part is chosen as the item to start the chart, all the operations performed upon it will be lined up in order along the right-hand side of the chart. The other parts are shown feeding into the major part at the proper points. It is comparatively easy to visualize the right-hand side of the chart as a progressive assembly line, and the horizontal material lines on the chart suggest feeder benches or subassembly lines feeding detail parts into the main assembly line.

A comparison of the operator process chart for a type K-02 filter box, Fig. 33, with the physical layout illustrated by Fig. 34 shows how clearly the chart suggests the layout. Even without a knowledge of the parts involved, one can recognize the layout as being logical for the process involved. Backtracking is avoided, and the operations are performed in an order and location that conform to the natural flow of material. Before the final layout is approved, it must be studied in accordance with the methods described in Chap. XIX; but a starting point for the study is found in the operation process chart and the initial layout that it suggests.

CHAPTER VIII

FLOW PROCESS CHARTS

The operation process chart contains a minimum of detail. For this reason, it is fairly easy to construct, and the information that it gives may be grasped quickly. At the same time, the information is limited and is not sufficient for certain kinds of more detailed study. When it is necessary to show in detail the exact manner in which a process is performed, describing what happens between operations as well as the operations themselves, the flow process chart is more suitable.

In form, the flow chart is somewhat like the operation process chart, but it gives more information. This is desirable on certain types of studies, but on others the mass of detail would be too great for ready interpretation. A complete flow process chart for the self-service charging rack (Fig. 32 of Chap. VII) would be so complex that it would be difficult if not impossible to interpret it correctly. On products of this kind, the operation process chart shows the problem more clearly. If after a preliminary study more detailed information is desired, flow charts can be made for the various parts that make up the complete assembly.

Uses of the Flow Chart.—The flow chart is used to follow men, materials, forms, or the like, through a complete process. Its chief applications may be summarized as follows:

1. Material:
   a. Unit.
   b. Assembly.
2. Man:
   a. Individual.
   b. Group.
3. Clerical procedure.
4. Miscellaneous.

The flow chart shows the different steps of a process such as operations, inspections, distance traveled, cessations of travel,

time required for each step, and any other pertinent information the one who is drawing it may wish to show. Flow charts are used in industry chiefly to reduce distance traveled and time that material spends in storage, to eliminate unnecessary operations and handling, and as a basis for improving plant layouts.

Because of the large amount of data usually presented on a flow chart, it is used more often to follow single material units through a process than it is for assemblies. It may be used satisfactorily for simple assemblies; but for more complicated products, it is used principally to show the flow of the most important parts, and the minor subassemblies are not included. Such products as cooking utensils, glass, tires, tubing, and pottery, where the final product is either a single piece of material or the assembly of a very few pieces, lend themselves to study by means of flow charts. More complicated assemblies such as clocks, electric motors, gasoline engines, air compressors, and even shoes are better studied by means of operation process charts, although individual parts of these assemblies such as the armature coils of an electric motor may well be studied in more detail by means of the flow chart.

The material of which a product is made is more commonly the item that is studied by flow charts; but on certain types of work, the movements of the man or men involved are more important. In the operation of reading gas or electric meters in the customer's house, a highly repetitive operation, no material is involved, but the movements of the man are of major importance. There is a superior way of doing even this comparatively simple operation, and a study by means of a flow chart will aid in determining what it is.

In clerical work, a form usually takes the place of material as the object to be followed. Flow charts are useful to show clearly all the steps followed by an order passing through the sales office, a time card through the shop and the pay-roll department, or a material requisition through the stores and stores-ledger routine.

Under the head of miscellaneous come more specialized flow charts such as those that might be drawn to trace the process by which a telephone call between New York and London is handled or those designed to make clear the workings of a transportation system. Special investigations require special charts, but the

principles upon which they are based are the same as for the industrial flow chart.

Symbols Used for Flow-chart Construction.—The earlier flow charts used about 40 different symbols to indicate the nature of the steps portrayed. Experience has shown, however, that too many different symbols detract from the clearness of the chart besides adding to the mechanical difficulties of chart construction, and modern practice therefore calls for the use of but six symbols. These are shown by Fig. 35, the two already given being repeated for the sake of completeness. These six symbols are easy to remember and are an aid in quickly interpreting the information shown by the flow chart. They are easily drawn either freehand or with the aid of ordinary drafting tools; or if many flow charts are to be constructed, small celluloid templates may be cut out and used.

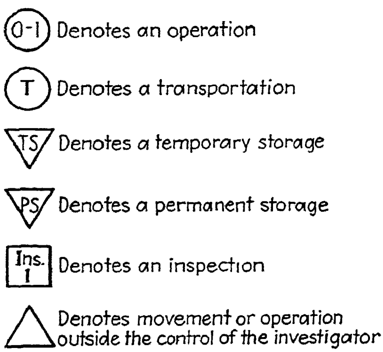


FIG. 35.—Standard symbols for flow process charts.

When the object being followed by the flow chart comes to rest and is not being worked upon or inspected, it is said to be in "storage." Strictly speaking, no industrial material probably ever goes into permanent storage, but the term is used in a relative sense. When a part goes into a storeroom or other storage space where it remains until some specific action such as the issuing of a requisition or a stores order puts it in motion again, it is considered to be in "permanent storage." When a part comes to rest in a space commonly devoted to manufacturing or processing and remains there awaiting a transportation, an operation, or an inspection that will be given it in due course as part of the processing procedure, it is said to be in "temporary storage."

Raw material before it is received, finished material after it is shipped, and material in process that is shipped away from a given plant for special processing are commonly not under the direct control of the manufacturer. Hence, their movements during these periods are not studied in detail, and a single symbol is used to show lack of control.

Constructing the Flow Process Chart.—Flow or the successive steps of a process are indicated on the flow chart by symbols joined together by a vertical flow line. Figure 36 shows a portion of a typical flow chart. This chart was drawn to show exactly what happened to a metal stamping from the time the raw material entered the plant until the completed product was ready for final assembly.

The chart starts at the upper left-hand corner of the sheet. Since most flow charts of single parts are long and narrow, it is customary to include two columns of the chart on the standard 8½- by 11-inch sheet. Each operation, transportation, inspection, or storage is noted on the chart by the proper symbol in the order in which it occurs. Operations and inspections are numbered. The time spent by the part at every step of the process is noted; and when the material is moved a distance greater than 5 feet, the number of feet moved is recorded also. As a result, considerable basic data are given which are necessary for a detailed methods study of the complete process.

Flow charts are quite simple to draw, but the gathering of the necessary data is not always easy. In most modern plants, a list of operations is available for any standard product, and where incentives based upon time study are used accurate time data for the operations are at hand. To find out what happens between operations, the analyst must either follow a part through the process himself or question in detail those who are closely connected with each step of the work. If the latter, he must word his questions in such a manner that he gets correct answers; for if no process-chart analyses have previously been made, the terms "temporary storage," "permanent storage," and perhaps even the others will not be clearly understood by those being questioned.

As soon as it is known when the various steps of the process occur, the construction of the chart can be begun. The symbols, operation and inspection numbers, and description of what occurs at each step are recorded first. Often, operation times and inspection times can be added from data already available. There remains then the task of determining the distances moved during transportation, operations, and inspections and the time consumed by transportations and by each temporary storage.

This information is not usually available, and it must be obtained by the analyst. The distances moved may be obtained

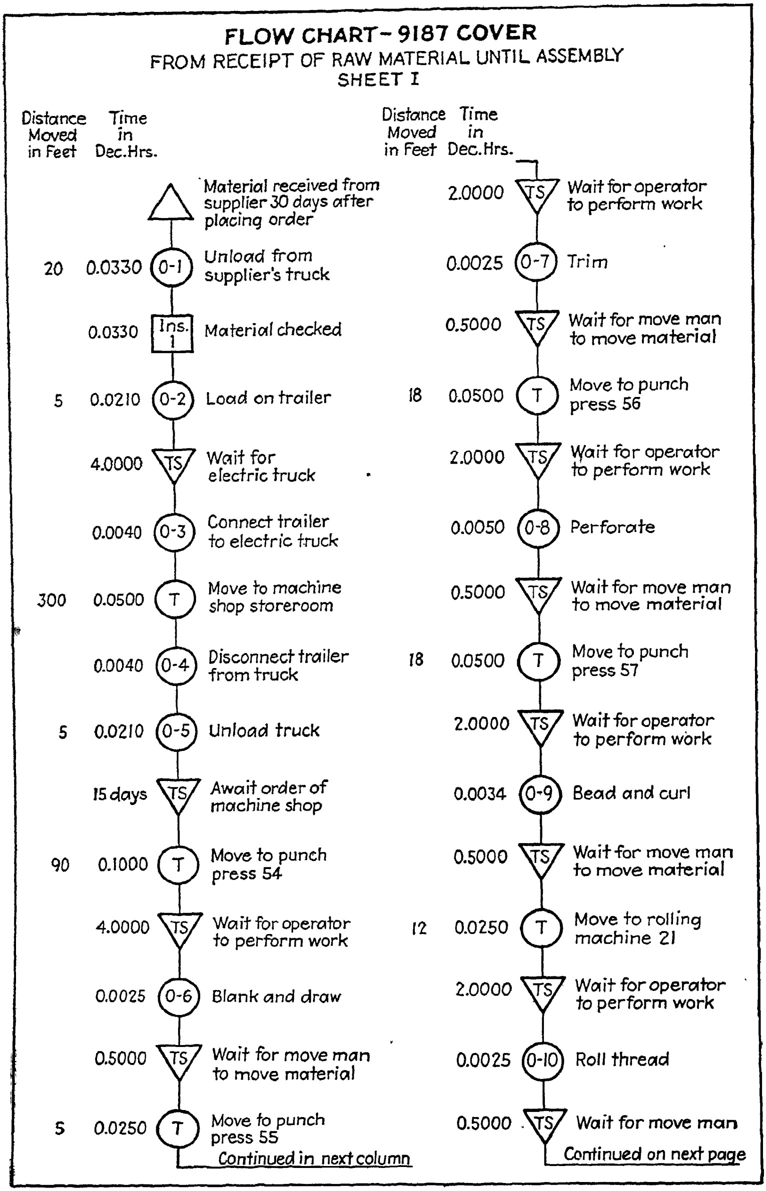


FIG. 36.—Portion of flow process chart of metal stamping.

from a layout of the manufacturing space, or they may be paced off by the investigator. Extreme accuracy is not particularly important, but estimating without investigating is not desirable. An error of 10 feet in a distance of 100 feet is not particularly serious; but if too much of the charting work is done at the desk without actually surveying the work space and the process with the problems of the study uppermost in mind, there is a good chance that possibilities for improvement may be overlooked and that the construction of flow charts will become mere mechanical routine.

Time consumed by transportations may be determined by brief time study. The mediums of transportation are usually few in number and remain the same from week to week. Thus, in a short time, data will be compiled from which it will be possible to determine a transportation time per foot for the various transportation means such as carrying, hand truck, electric truck, tractor-trailer train, traveling crane, and so on. When these data are available, transportation time can be determined without actual time measurement.

The time spent by the product in temporary storage is not so easy to determine, for it is likely to vary considerably from order to order, or even from day to day. When the plant becomes overloaded, time spent by material in temporary storage increases. Where miscellaneous work is done, the jobs which receive special attention from the production department spend less time in temporary storage than those which do not.

Temporary storage time is best determined by making a number of actual observations and averaging the results. Because the time spent in temporary storage is relatively long, however, there is a tendency to resort to estimating. This is undesirable; for since the amount of time spent in temporary storage is not a factor that is likely to have received much previous consideration, the estimates are likely to be even more inaccurate than estimates of operation times. In certain studies, time spent in temporary storage is one of the most important factors, for these studies are made primarily to decrease the time required to complete the process. Hence, it is important to have correct temporary storage data if improvement is to be made.

Typical Flow-chart Study.—The following description of an analysis made of the operations performed in filling an order in

the stores and shipping department of a certain manufacturing organization will indicate the kind of results that may be expected from a methods study based upon flow charts.

In this particular plant, practically all orders received were rush orders, and it was important that they should be filled and shipped as quickly as possible. When the plant was small, orders moved out rapidly; but as the volume of business expanded and the number of orders increased, the stores and shipping department—which operated under one head in this plant—began to experience increasing difficulty in filling orders as promptly as the supervisor felt could be done. As a result, he requested that an investigation be made.

A methods engineer was assigned to the job, who with the assistance of the stores and shipping-department supervisor, drew up the flow chart illustrated by Fig. 37. This chart showed one interesting point at once. Five and one-quarter hours on the average were spent by each order in temporary storage waiting for something to be done to it. Since the total time required to fill an order was only 6.1252 hours, it was apparent that the routine would have to be improved so that the time spent in temporary storage could be reduced.

Reference to the flow chart will show that the first delay occurred as soon as the orders arrived in the stores and shipping department. Investigation showed that there was no systematic procedure for starting orders through the routine and that they waited, on the average, ½ hour in the "mail in" basket before they were even looked at.

When at length the orders were stamped and sorted, there was another delay while they were being filled. Each order was filled separately under the system in effect, a process necessitating much walking. While one order was being filled, the rest had to await their turn.

When the material to fill a given order was collected, it was placed on a bench in the shipping department. There it waited until an assistant foreman, who was often occupied with other duties, could check it over. When it was checked, it waited again until the packers could get it packed. When surveying the packing operation in order to construct the flow chart, the methods engineer noted that the layout of the packing work area was far from efficient. At the proper time, he took this up

FLOW OF ORDERS THROUGH SHIPPING DEPARTMENT
(ORIGINAL METHOD)

Distance moved in feet	Time Dec. Hrs.		
210	0.1670	△	Orders brought from Stores Ledger Department by messenger and placed in "Mail in" basket
	0.5000	TS	Wait in basket to be collected
	0.0080	O-1	Orders removed from mail basket
26	0.0032	T	Carry to sorting table
	0.0040	O-2	Sort, stamp, and place in shipping order
	1.0000	TS	Waiting to be filled
	0.0070	O-3	Top order picked up and read by shipping clerk
50	0.0040	T	Order carried to material storage bins
	0.1400	O-4	Material collected to fill order
50	0.0040	T	Material carried to shipping bench
	0.2500	TS	Wait for checking
	0.0350	Ins 1	Recheck order for errors
	0.5000	TS	Wait to be packed
15	0.0060	T	Move to packing bench
	0.1000	O-5	Pack order in carton
80	0.0080	T	Carry to postal bench
	0.2500	TS	Wait for mail clerk
	0.1000	O-6	Label and insure package
3	0.0050	T	Place on floor
	2.0000	TS	Wait for address and insurance to be checked
	0.0300	Ins 2	Check parcel against order
20	0.0040	T	Carry filled order to "Mail out" basket
	0.0020	O-7	Place filled order in basket
	1.0000	TS	Wait for messenger
		T	Messenger - To accounting department
454	6.1272		

FIG. 37.—Flow process chart of original stores and shipping department procedure.

with the supervisor, and together they worked out an improved layout which reduced packing time. This in turn, of course, reduced the time spent by orders in temporary storage awaiting packing.

To return to the procedure at the time of the investigation—when the order was packed, it was placed on the floor to be checked again by the assistant foreman, this time for correct addressing. Investigation showed that the foreman was in the habit of waiting before checking until a large pile of packages was ready, although by so doing outgoing mails were frequently missed.

When the package was finally checked, the order itself was sent to the accounting department where an invoice was prepared. This again involved temporary storage which was undesirable, for prompt billing means quicker collection of accounts.

With the points of inefficiency clearly brought out by the flow chart, it was a comparatively simple matter for the stores and shipping-department supervisor and the methods engineer to work out a better method of handling orders. First, a pneumatic carrier was installed between the sales and the stores department. This eliminated the messenger and insured the orders reaching the stores department a few seconds after the sales department had completed its work upon them.

When the orders reached the group leader in charge of the storeroom attendants, he immediately stamped and sorted them and gave them to the storeroom attendants assigned to the different classes of material handled. Each storeroom attendant was provided with a truck having a body divided into a number of bins. He filled all orders given him, placing the material for each order in a separate bin, and then pushed the truck to the packing bench, notifying the assistant foreman that it was ready for checking.

After checking, there was a delay while orders were awaiting packing; but this could not be eliminated, for it would be impractical to provide enough packers to pack all orders the instant they were checked. Because of the improved packing layout, the delay was not great and was considered relatively unimportant.

When orders were packed, they were placed aside for checking as before. The assistant foreman's work was scheduled, how-

ever, so that he checked packages at regular half-hour intervals. In this way, each package was delayed only 15 minutes on the average; and since checking periods were arranged to conform

FLOW OF ORDERS THROUGH SHIPPING DEPARTMENT
(IMPROVED METHOD)

Distance moved in feet	Time Dec. Hrs.		
			Orders received from Stores Ledger Department by chute
	0.0088	TS	Wait to be collected (Bell notifies storekeeper)
	0.0060	O-1	Orders removed from chute
5	0.0015	T	Carry to sorting table
	0.0040	O-2	Sort, stamp, and place in shipping order
15	0.0030	T	Place on collecting truck and push to bins
	0.1400 per order	O-3	Material collected to fill all orders on hand
50	0.0040	T	Material carried to packing bench
	0.0350	Ins 1	Recheck orders for errors
	0.2500	TS	Wait to be packed
	0.0650	O-4	Pack order in carton
2	0.0015	T	Push across bench to be labeled and insured
	0.0050	O-5	Label and insure package
3	0.0050	T	Place on floor
	0.2500	TS	Wait for address and insurance to be checked
	0.0300	Ins 2	Check parcel against order
	0.0030	O-6	Place order in tube carrier
		T	To accounting department
75	0.8718		

FIG. 38.—Flow process chart of improved stores- and shipping-department procedure.

to outgoing mail schedules, all packages were shipped as quickly as they could be. As soon as the packages were checked, the assistant foreman placed the order forms in the pneumatic

carrier which sent them at once to the accounting department where invoices were immediately made up and mailed out to the customer.

Figure 38 shows the flow chart of the new procedure. It will be noted that the time required to fill an order was reduced to 0.8718 hour, a reduction of 85.8 per cent. Thus, the major purpose of the investigation was accomplished. In addition, through the various improvements that were made, the distance each order traveled in the stores and shipping department was reduced from 194 to 75 feet, and the services of a messenger were eliminated. The number of operations was reduced from 7 to 6, the number of transportations from 8 to 6, and the number of temporary storages from 7 to 3. Finally, the average packing time per order was reduced from 0.1000 to 0.0650 hour, as the result of improved workplace layout.

Results of Flow-chart Analysis.—The results described in this example are typical of the improvements made as the result of a flow-chart analysis. On larger and more complicated work, the results of such studies are even more striking although proportionately the same.

Such improvements naturally result in worth-while operating economies. Thus, although it unquestionably requires some little time to draw up a flow chart, the savings obtained on repetitive work will many times offset the expense involved. While speaking of results, it may be well again to emphasize the fact that the flow chart itself does not make the improvements. It merely arranges the data and presents the problem in such a way that opportunities for improvement become apparent to those who are conducting the studies.

Flow Charts and Plant-layout Study.—In Chap. VII, the manner in which operation process charts may be used to assist in laying out the proper location of machines and equipment was briefly pointed out. The general locations are determined in this manner; but before the exact location can be fixed, more detailed information must be available. The flow process chart is useful in this connection.

In addition to the information given by the operation process chart, the flow chart shows distances moved and time spent in temporary storage. If the distances moved appear excessive, equipment should be relocated to reduce transportations to a minimum.

Information about temporary storage is particularly important. If there is no way of eliminating temporary storage, then space must be provided for the material in temporary storage. Otherwise, congestion will result. The amount of space required for temporary storage may be determined from the size of the material, its rate of flow, and the duration of the temporary storage.

Material in temporary storage is often referred to as a material "bank." In progressive operations where the steady performance of a group of men is dependent upon the steady flow of work through a process, banks of material are especially important. It is often possible to work out a setup in which all operations are of approximately the same length, so that as one man lays aside his completed piece, the operator following him is just ready to receive it and the operator ahead of him is just ready to pass the next piece to him. In such setups, all temporary storage is eliminated, and theoretically there should be no need of material banks. It often happens, however, that there is a likelihood of delay at certain parts of the process. Certain dies may be likely to break, or a machine may require periodic adjustment. Wherever there is a likelihood that an interruption may occur, a material bank should be provided. This bank will be used only in case of emergency, and its size will be sufficient to cover only a reasonable period of interruption. When a machine or operation is down, the next operator will obtain his material from the emergency bank, and production will be uninterrupted.

It must be remembered that, in a case of this kind, the operator just ahead of the breakdown point must have space to set aside the parts that he finishes and allowance must be made accordingly. These parts can be processed at the next operation and used to replenish the emergency bank during an overtime work period.

Flow Charts as an Aid to the Study of Office or Clerical Routine.—Office work is commonly handled with the aid of various forms. Where the office routine is at all complicated, it is difficult to visualize the purpose of each form, its course through the office, its relation to other forms, and the time consumed in passing through the routine.

A flow chart shows all this most clearly and paves the way for simplifying the procedure. In many cases, several forms which

originally were filed in as many different files are combined into one form, kept in one file, as the result of careful study. Clerical routine is often established rather haphazardly as business expands and, unless it is studied from time to time, is likely to become cumbersome.

Figure 39 shows a flow chart that was drawn up to assist in studying the clerical routine followed by an inventory control department in issuing stock orders and checking their progress through to the point of completion.

Process Charts as a Supervisory Aid.—Enough has been said about the operation and flow process charts to show that their construction is not a highly technical accomplishment. The operation process charts are especially simple to prepare, but even flow charts are not particularly difficult. The steps that require timing are comparatively long and may be measured with an ordinary watch. A knowledge of the detailed time-study procedure is unnecessary.

Therefore, operation- and flow-process-chart construction need not be limited to methods engineers. The charts can be constructed by anyone who has a problem to solve and who is willing to take the time to understand and apply the comparatively simple principles of process-chart preparation. Thus, the superintendent, foreman, accountant, sales manager, or supervisor or anyone else who takes an interest in bettering the work that he directs not only can but should make full use of process charts in this connection.

Although, at the present time, the use of process charts is largely confined to methods engineers, certain more progressive plants have given courses in methods engineering to their key supervisors. Where these courses have emphasized the importance and value of process charts, the result has been that the foreman and others have adopted this tool for their own and have used it freely to work out better methods and as a means of presenting suggestions for improvement to their management. In other words, where proper instruction has been given, it has been demonstrated that process charts are a practical, everyday tool well suited for general use.

Process Charts in the Jobbing Shop.—Although process charts are often thought of as applicable only to highly repetitive work, they are as important to the jobbing shop as they are to

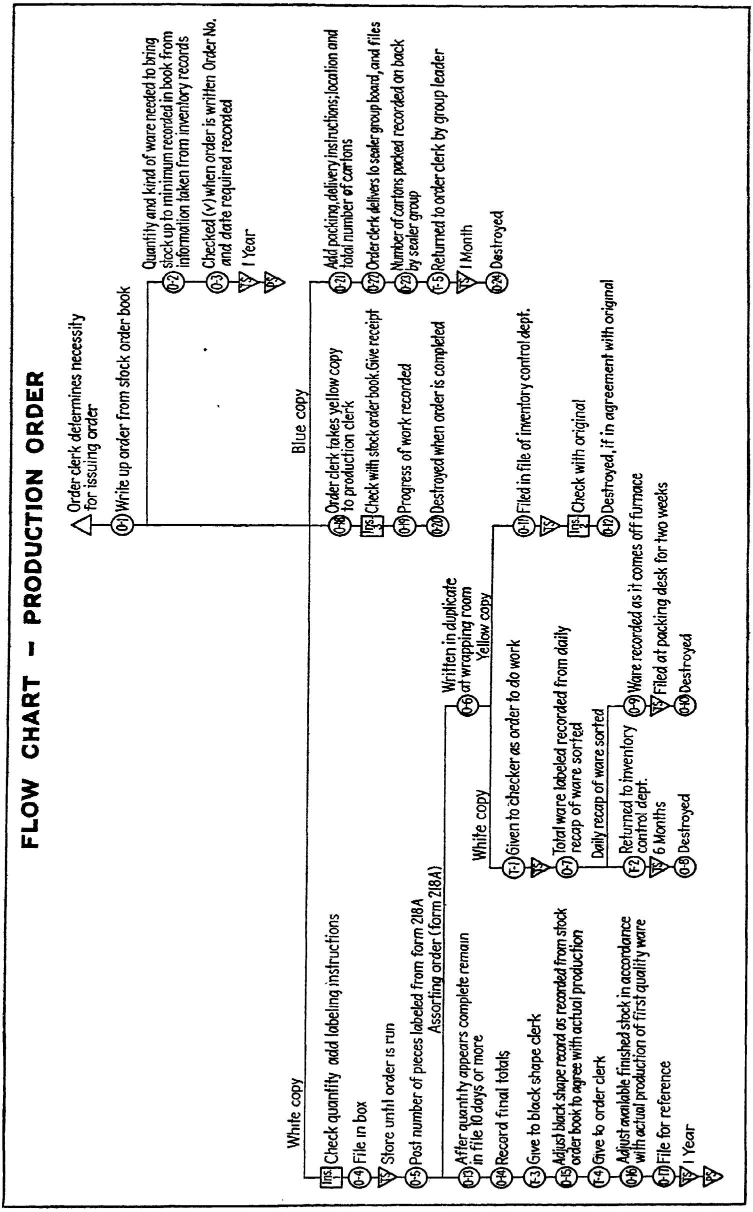


FIG. 39.—Flow process chart of clerical routine followed by inventory control department in placing and following stock orders.

the mass-production shop. Perhaps they should be considered even more important; for where a wide variety of product is handled, it is difficult to get a clear picture of the various processes involved.

In preparing process charts in the jobbing shop, jobs that are considered to be representative of the various classes of work handled should be selected. Process charts should be prepared for these jobs, and each step should be subjected to detailed analysis. Although the improvements that are made for any one job may result in only a small saving, if the same improvements can be applied to other similar jobs, the total saving is likely to be large. The relocation of a storeroom, for example, may reduce transportation distance for all jobs that go through the shop.

General and Detailed Analysis.—Job analysis progresses from a broad sweeping analysis to a type of analysis that becomes more and more detailed. At first, a general analysis is made for the purpose of determining what kind of methods study is to be made. On the assumption that it is practical to do so, another form of analysis is next made by means of operation and flow process charts. This analysis is still rather general in nature. It presents the problem and suggests ways of eliminating major inefficiencies. It presents the process as a whole for analysis, however, rather than the details of each operation.

The next step, therefore, is to bring to bear a more refined type of analysis upon the operations themselves. With the general nature of the problem understood and with the major inefficiencies either recognized or eliminated, the analyst is in a position to begin a study of each operation involved in the process with the idea of improving upon the operations themselves. The manner in which this detailed analysis may best be accomplished will be described before the other types of process charts are discussed, for these other charts are themselves used for detailed operation study and are usually constructed only after a detailed analysis of the factors that surround a given operation have shown that they are needed.

CHAPTER IX

THE ANALYSIS SHEET

The entire process commonly known as "operation analysis" consists principally of finding out all known facts that affect a given operation. This is accomplished by adopting a questioning attitude toward the job and examining minutely every detail connected with it. Common sense, of course, must be used in interpreting this statement, for it would be possible to examine each point so extensively that a year or more would be spent in analyzing a single operation. In practical work, the methods engineer considers, at least briefly, every detail that is likely to affect operating time. Experience leads to the recognition of the points at which the greatest possibilities for improvement lie, and the major part of the study will be made on them.

Importance of Systematic Procedure.—In Chap. II, the type of question that is asked by the analyst was described. The list given was by no means complete, for its purpose was merely to illustrate the kind of detailed investigation made. In the following chapters, as each phase of operation analysis is discussed, thought-provoking questions are listed. These questions have for the most part a general application. The list could be still further extended if questions relating to a given trade or industry were formulated, but such questions would be of limited value here. An organization that is using the operation-analysis procedure extensively can profitably add specific questions that will apply to specific types of work.

In making an analysis, there are so many questions which should be asked that unless a systematic procedure is followed it is quite possible that certain points, perhaps of cardinal importance, may be forgotten. More than one analysis has proceeded to the point where elaborate suggestions for improving the operation have been presented only to have all the work discarded because the tardy consideration of a simple question like "What is the purpose of the operation?" has disclosed the

fact that the operation can be eliminated or combined with another operation or improved in some other simple and direct manner.

To avoid wasted effort, then, and to make sure that all important points are considered, the analyst should keep clearly in mind certain factors that should be examined in every operation. These factors should be considered in the order of the likelihood of their bringing out major possibilities for improvements. They should be considered in detail whether the analysis is mental or written.

Nine Points of Primary Analysis.—There are nine main points or factors that should be considered in every operation analyzed. These, arranged in order of importance, are as follows:

1. Purpose of operation.
2. Complete survey of all operations performed on part.
3. Inspection requirements.
4. Material.
5. Material handling.
6. Setup and tool equipment.
7. Common possibilities for job improvement.
8. Working conditions.
9. Method.

The analysis is made for the purpose of improving the method of doing the operation, and it might seem that this point should be considered first. All the other factors, however, influence the method directly or indirectly; and until they have been studied and improved as much as possible, it is inadvisable to begin a too detailed analysis of the method. In actual practice, it is seldom possible to complete the analysis of one factor at a time and then leave it for good. Several of the factors, as for example setup and method, are interdependent, and a change in one will cause a change in the others. The list, however, indicates in a general way the course along which the analysis should proceed.

Mental Job Analysis.—It has been pointed out that an analysis which is made by observation alone may be either mental or written. The mental analysis is, of course, the quicker, but it is also the less satisfactory. Records of the steps of the analysis, if any are kept, are not systematic or complete; and if the job has to be restudied for any reason, the analytical work must be

repeated. Because of the quickness with which mental analyses can be made, they are used on jobs where low activity or labor expenditure makes it uneconomical to make an elaborate analysis. A mental analysis is far superior to no analysis at all and should be made at least briefly before time measurement is begun.

On work of a jobbing nature, the conditions surrounding the class of work as a whole should be analyzed in considerable detail the first time the work is subjected to detailed study. Such factors as material handling and working conditions should be gone into thoroughly, and all improvements that seem advisable should be made at once. Then, when individual jobs are studied, it will not be necessary to analyze repeatedly these factors, which are common to all jobs, and full attention may be directed to those factors which concern only the operation being studied.

Mental analyses if systematically made will produce many good results. Indeed, many industrial plants today make no use of written analyses but rely solely on mental analysis to bring about the results they wish to obtain.

The danger in this type of analysis is that some factor will be overlooked or at least be questioned too briefly. It is easy to give an improperly considered answer to a question when the answer need not be committed to writing. The necessity of recording a clear and concise answer on paper insures that the question will receive proper consideration.

If, however, conditions make mental analysis necessary, the analysis should be conducted systematically. The analysis sheet described below is used when making a written analysis to insure that none of the nine points of primary analysis will be left unconsidered. The general arrangement of this form, therefore, may profitably be memorized. It can then be followed step by step in making even a brief mental analysis, with the result that when the analysis is completed one can be certain that no step has been overlooked.

Written Analysis.—Several of the advantages of the written analysis have been mentioned during the discussion of the mental analysis. When an analysis is reduced to writing, it is more likely to be carefully made. Each one of the nine factors will receive due attention. In addition to these points, the analysis

Date .... Dept. .... Dwg. .... Sub ....
Mould .... Die .... Style .... Item ....
Pattern .... Ins. Spec. .... L. Spec. .... Sub. ....
Part Description ....
....
Operation .... Operator ....

DETERMINE AND DESCRIBE	DETAILS OF ANALYSIS
1. PURPOSE OF OPERATION	Can purpose be accomplished better otherwise?
2. COMPLETE LIST OF ALL OPERATIONS PERFORMED ON PART No. Description Work Sta. Dept. 1. .... 2. .... 3. .... 4. .... 5. .... 6. .... 7. .... 8. .... 9. .... 10.	Can oprn. being analyzed be eliminated? be combined with another? be performed during idle period of another? Is sequence of oprns. best possible? Should oprn. be done in another dept. to save cost or handling?
3. INSPECTION REQUIREMENTS a—Of previous oprn. b—Of this oprn. c—Of next oprn.	Are tolerance, allowance, finish and other requirements necessary? too costly? suitable to purpose?
4. MATERIAL Cutting compounds and other supply materials	Consider size, suitability, straightness, and condition. Can cheaper material be substituted?
5. MATERIAL HANDLING a—Brought by b—Removed by c—Handled at work station by	Should crane, gravity conveyors, totepans, or special trucks be used? Consider layout with respect to distance moved.
6. SET-UP (Accompany description with sketches if necessary) a—Tool Equipment Present Suggestions	How are dwgs. and tools secured? Can set-up be improved? Trial pieces. Machine Adjustments. Tools Suitable? Provided? Ratchet Tools Power Tools Spl. Purpose Tools Jigs, Vises Special Clamps Fixtures Multiple Duplicate

Methods Engineering Council
Form No. 101

ANALYSIS SHEET

FIG. 40.—Analysis sheet form—front.

sheets, if accessibly filed, will often prove valuable for future reference, since they show most completely the conditions that existed at the time the study was made. They will also prove valuable at a later date when making reports of accomplishment.

In brief, written analyses offer the same advantages that any other class of written records offers. Hence, it is strongly recommended that written analyses be used wherever methods studies are conducted.

The Analysis Sheet.—In order to simplify the work of making written analyses, a form known as the "analysis sheet" has been designed by the Methods Engineering Council. Since its introduction, its use has spread rapidly, for it has been shown that wherever it is regularly used, suggestions for improvement increase. The form, of course, does not accomplish this through any mystic property of its own, but its use insures that none of the factors which should be considered will be neglected. In securing the information needed to fill out the form completely, one will be certain to make a complete analysis.

The front of a blank analysis-sheet form is shown by Fig. 40 and the back by Fig. 41. At the top of the form on the front side, space is provided for identifying completely the analysis, the part, and the operation. This should be filled in carefully before the analysis is begun. It should be unnecessary to stress the importance of identifying carefully all the paper work connected with methods studies. Questions arise from time to time regarding processes and operations, particularly if the work has been measured and is performed on an incentive basis, and it may frequently be found necessary to refer to the analysis sheets, time studies, and process charts that have been made out for a certain job. Hence, all papers should be clearly marked and kept where they can be found. Unfortunately, experience shows that unless this point is emphasized and reemphasized identification of papers is seldom complete.

The reason is easy to understand. Filling in an analysis sheet or taking a time study requires considerable concentrated effort. The work is interesting, even absorbing. When completed, all details concerning the job are freshly in mind. It does not seem possible that they ever could be forgotten. Hence, complete identification of papers is slighted because it is considered unimportant, forgotten completely, or postponed and

7. CONSIDER THE FOLLOWING POSSIBILITIES.
1. Install gravity delivery chutes.
2. Use drop delivery.
3. Compare methods if more than one operator is working on same job.
4. Provide correct chair for operator.
5. Improve jigs or fixtures by providing ejectors, quick-acting clamps, etc.
6. Use foot operated mechanisms.
7. Arrange for two handed operation.
8. Arrange tools and parts within normal working area.
9. Change layout to eliminate back tracking and to permit coupling of machines.
10. Utilize all improvements developed for other jobs.

RECOMMENDED ACTION

8. WORKING CONDITIONS

a—Other Conditions

Light
Heat
Ventilation, Fumes
Drinking Fountains
Wash Rooms
Safety Aspects
Design of Part
Clerical Work Required (to fill out time cards, etc.)
Probability of Delays
Probable Mfg. Quantities

9. METHOD (Accompany with sketches or Process Charts if necessary)

a—Before Analysis and Motion Study.

b—After Analysis and Motion Study

Arrangement of Work Area
Placement of
Tools.
Materials.
Supplies.
Working Posture
Does method follow Laws of Motion Economy?
Are lowest classes of movements used?

See Supplementary Report Entitled

Date

OBSERVER .... APPROVED BY ....

FIG. 41.—Analysis sheet form—back.

forgotten. Too often, in the glow of satisfaction which comes from working out improvements that facilitate operations and result in substantial cost reductions, the importance of the details of identification is dimmed.

The time comes, however, when it becomes vitally important to check back on certain details of a job. If the papers cannot be found, serious troubles are likely to result, and quick and usually expensive action will be necessary to overcome the difficulty.

For example, a certain plant used a number of time formulas for establishing time allowances. At the time the formulas were compiled, the work was carefully analyzed, and the formulas were set up to take care of the conditions that then existed. In the press of work required to install the formulas, the papers describing the analysis were hurriedly filed away and were soon lost. The formulas, however, were accurate, the operators were satisfied, and no particular concern was felt, even if it was realized at the time that the papers were lost, which is doubtful.

Several years passed. From time to time certain minor changes and refinements in equipment and methods were made which, though too small individually to warrant a formula revision, had the cumulative effect of causing the time allowances to become loose over a period of time. Labor costs rose out of proportion to the effort expended, and it was finally decided that a revision was in order.

The operators involved had always taken a keen interest in matters pertaining to time-study work. When the revision was proposed, since there had been no recent changes in conditions or methods, they at once asked why the revision was to be made. Vague references to changes did not satisfy them. They wanted, and justly so, to be shown what the changes were and how they affected operating time. This could not be shown definitely because of the lack of records, and finally the proposed revision had to be abandoned. The company continued to pay more than the work was worth because rates were guaranteed unless methods changed, and they could not prove that changes had occurred.

Presently the effects of a depression reached this department. Work was scarce, and the operators faced short time. The time allowances were questioned closely. Questions were asked concerning how time was allowed for various elements and how

certain miscellaneous operations were cared for. Again, because of the lack of records, it was impossible to answer convincingly. The men who had originally made the formulas had since left the department, and there was no satisfactory way of determining the factors upon which certain parts of the formulas were based.

The point was finally reached where, in order to maintain its reputation for fair dealing, the company was forced either to increase time values to care for operations that it was morally certain were already covered or at considerable expense to make a complete restudy of the work. Either course was satisfactory to the workers, who were fair-minded and willing to abide by the results of time study, and eventually the restudy was made.

Considerable space has been devoted to stressing the importance of adequate records and identification, for experience has shown that the majority of shop supervisors above the grade of clerk do not realize their vital necessity. In the case cited, lack of records at one time prevented an adjustment of rates that was entirely justified and later brought on the threat of an upward revision that was not necessary.

It should be noted in passing that when management tries to be scrupulously fair at all times with the men, inadequate records nearly always are costly to the company. Conversely, proper records act as a protection to the workers if an unjustified reduction is considered. The methods engineer, to do his job properly, must be fair to both employers and employees. If he maintains proper records, he is in a position to justify his work at any time.

In this discussion, it should be borne in mind that necessary records only are being referred to. Some individuals or firms have a tendency to preserve every paper, letter, or report regardless of its importance. Before a decision is made, the files are searched to see what others have done, said, or thought about the subject, and often undue importance is attached to the work that was done in the past. Such a procedure and attitude are quite likely to act as a brake on progress and have led some extremists to state that files and records should be dispensed with altogether. This is, of course, as undesirable as the other attitude, for adequate records are an essential part of effective management.

Item 1.—With the analysis sheet properly identified, the analysis is begun. The first point considered is the purpose of

the operation. If analysis shows that the operation serves a definite purpose, various other means of accomplishing the same result are considered to see if a better way can be found.

Item 2.—If operation or flow process charts have not been constructed, all the operations performed on the part are next listed. The purpose of this is to determine just how the operation being analyzed fits in with the other operations that are performed on the part. This study frequently brings to light the fact that the operation being analyzed can be eliminated altogether or that, by combining it with other operations or performing it during the idle period of another operation, the time for doing it can be materially reduced. Again, it is sometimes found that the sequence of operations is not the best possible and that unnecessary work is being performed for this reason. Another common condition which is discovered at this stage of the analysis is that the part is being shipped about among departments more than is necessary. It may be that, instead of sending a part to a distant department to have a simple operation performed upon it, it would be better to move the work station. These possibilities and all others mentioned here will be covered more fully in the chapters devoted to a complete discussion and illustration of each of the nine points of primary analysis.

Item 3.—The inspection requirements of the job must be looked into thoroughly, for the accuracy required has a direct bearing on the methods used to produce the work. The analyst himself usually has no voice in establishing inspection requirements, but he should consider it his duty to investigate them in order to satisfy himself as to their necessity. Occasionally, inspection requirements are hurriedly and incorrectly established, and a subsequent check will bring this to light. Usually, the requirements err in the direction of unnecessary accuracy; for if the requirements are too loose, the part will not function properly in the final assembly and the error will be caught. Occasionally, however, the analyst will find that if the requirements are made more exacting on one operation, a subsequent operation will be made easier to perform.

Item 4.—The material of which the part being studied is made is specified by the design engineer and theoretically should not concern the analyst. Design engineers, however, like all other human beings are not infallible and sometimes specify an

unnecessarily costly material. It is proper and necessary that the methods engineer should check on cases of this kind and bring them to the attention of the designers.

In other cases, certain materials present shop difficulties that may not be known to the designer. A certain cheap, brittle material may be so difficult to machine that an excessive amount of scrap results. Here investigation might show that it would be less expensive in the end to specify a more costly but more easily machined material.

Item 5.—Material handling is a study in itself. That it has received a great deal of attention on the part of management is evidenced by the wide application of conveyers, cranes, trucks, and other mechanical handling devices. Manual handling, however, is encountered frequently, and should be carefully studied where found. Handling problems are as numerous and varied as the parts handled, but they offer a fertile field for savings. In general, the part that is the least handled is the best handled.

Although it is commonly thought that conveyers can be used to advantage only in mass-production work, there are types on the market that are equally successful in jobbing work. Not only do the latter conveyers eliminate material-handling labor, but if they are used in conjunction with a dispatching system they permit far better production control than is usually obtained in miscellaneous, small-quantity work. A full description of this type of conveyer system is given in Chap. XV.

Many plants are laid out, if a careful study has not been made, so that a great deal of unnecessary handling is required, particularly if the plant has gone through a period of rapid expansion. Major changes of layout do not usually result from the analysis of a single job, although they may. However, the matter of general layout should be given at least passing consideration under items 2, 5, and 8 of the analysis sheet. As a result of this preliminary work, the analyst will be in a good position to undertake a major layout revision when the occasion arises.

Item 6.—The term "setup" is loosely used throughout industry to signify the workplace layout, the adjusted machine tool, or the elemental operations performed to get ready to do the job and to tear down after the job has been done. More exactly, the arrangement of the material, tools, and supplies that is made

preparatory to doing the job may be referred to as the "workplace layout." Any tools, jigs, and fixtures located in a definite position for the purpose of doing a job may be referred to as "being set up" or as "the setup." The operations that precede and follow the performing of the repetitive elements of the job during which the workplace layout or setup is first made and subsequently cleared away may be called "make-ready" and "put-away" operations. For the sake of clearness, the more exact phraseology will be used throughout this book, although the workplace layout, the setup, and the make-ready and put-away operations are all considered under item 6 on the analysis sheet.

The workplace layout and the setup, or both, are important because they largely determine the method and motions that must be followed to do the job. If the workplace layout is improperly made, longer motions than should be necessary will be required to get materials and supplies. It is not uncommon to find a layout arranged so that it is necessary for the operator to take a step or two every time he needs material, when a slight and entirely practical rearrangement of the workplace layout would make it possible to reach all material, tools, and supplies from one position. Such obviously energy-wasting layouts are encountered frequently where methods studies have not been made and when encountered serve to emphasize the importance of and the necessity for systematic operation analysis.

The manner in which the make-ready and put-away operations are performed is worthy of study, particularly if manufacturing quantities are small, necessitating frequent changes in layouts and setups. On many jobs involving only a few pieces, the time required for the make-ready and put-away operations is greater than the time required to do the actual work. The importance of studying carefully these nonrepetitive operations is therefore apparent. When it can be arranged, it is often advisable to have certain men perform the make-ready and put-away operations and others do the work. The setup men become skilled at making workplace layouts and setups, just as the other men become skilled at the more repetitive work. In addition, on machine work it is usually possible to supply them with a standard tool kit for use in making setups, thus eliminating many trips to the locker or to the toolroom.

The tool equipment used on any operation is most important, and it is worthy of careful study. Repetitive jobs are usually tooled up efficiently, but there are many opportunities for savings through the use of well-designed tools on small-quantity work which are often overlooked. For example, if a wrench fits a given nut and is strong enough for the work it is to do, usually little further attention is given to it. There are many kinds of wrenches, however. The list includes monkey wrenches, open-end wrenches, self-adjusting wrenches, socket wrenches, ratchet wrenches, and various kinds of power-driven wrenches. The time required to tighten the same nut with each type of wrench is different. The more efficient wrenches cost more, of course, but for each application there is one wrench that can be used with greater over-all economy than any other. Therefore, it pays to study wrench equipment in all classes of work. The same remarks apply to other small tools.

Jigs, fixtures, and other holding devices too often are designed without thought of the motions that will be required to operate them. Unless a job is very active, it may not pay to redesign an inefficient device, but the factors that cause it to be inefficient may be brought to the attention of the tool designer so that future designs will be improved.

Item 7.—There are a number of changes that can be made to workplace layouts, setups, and methods which are brought to light by job analysis. Of these, there are 10 that are encountered frequently, and 1 or more may be made on nearly every job studied. These 10 common possibilities for job improvement are listed under item 7 on the back of the analysis sheet and are as follows:

1. Install gravity delivery chutes.
2. Use drop delivery.
3. Compare methods if more than one operator is working on same job.
4. Provide correct chair for operator.
5. Improve jigs or fixtures by providing ejectors, quick-acting clamps, etc.
6. Use foot-operated mechanisms.
7. Arrange for two-handed operation.
8. Arrange tools or parts within normal working area.

9. Change layout to eliminate backtracking and to permit coupling of machines.
10. Utilize all improvements developed for other jobs.

These improvements are comparatively easy to make. If the analyst is observant and on the alert for inefficient operating practices, the possibility of applying them can be recognized without resorting to detailed motion or time study. Specific applications of each point will be discussed later.

Item 8.—Working conditions have an important influence on production. This has been widely recognized during recent years, and the more modern plants usually provide working conditions that the methods engineer considers to be suitable. In the older plants, or in modern plants where methods studies have not been made, poor working conditions are frequently encountered. In most cases, it is best to correct them. It is sometimes difficult to justify the cost of making such improvements by direct labor savings, but there are other factors that must be considered in this connection. The human element cannot be neglected. Conditions that are unhealthy, uncomfortable, or hazardous breed dissatisfaction. Besides lowering production, they increase labor turnover and accidents and often lead to labor unrest.

There are certain other factors that are worthy of at least passing consideration during analysis, and the most important of these are listed as "other conditions" under item 8. The design of the part, of course, plays an important role in the methods that must be used to produce it. In the majority of cases, the design is fixed by the engineering, functional, or appearance requirements of the product, but occasionally a part is encountered that can be redesigned to make its production easier without in any way affecting its ultimate purpose. In addition to this, certain minor features of design can sometimes be suggested that will help to fit the product to the limitations of the tools which are to produce it.

Item 9.—The analysis of the method followed in performing the operation is the most important part of the study. The consideration of the method is seldom, if ever, complete at the time the analysis sheet is filled in but goes on in one form or another during the remainder of the time the job is studied.

The method that is established after analysis and motion study is recorded under 9*b* in order that the analysis sheet may provide a complete record of the job, although, strictly speaking, this information does not belong under the head of analysis.

Usually the analysis of the method requires the drawing of one or more types of process chart, and often a number of computations are involved. This information should be gathered together in the form of a supplementary report and identified by a note on the analysis sheet.

The foregoing gives a general description of the items on the analysis sheet. Specific methods of approaching the analysis of each item, illustrated by examples taken from industry, are given in the chapters that follow.

CHAPTER X

USE OF THE ANALYSIS SHEET

The analysis sheet acts as a guide to systematic operation analysis. It directs the analyst step by step through the various factors that should be considered and insures that none will be overlooked.

The analysis itself takes place in the mind of the analyst. He questions each point as it is raised, ascertains all known facts, and upon the basis of the information thus gained arrives at suggestions for improvement. The nature and extent of these suggestions depend largely upon the originality, inventiveness, and experience of the analyst. Any given investigator, however, will accomplish greater results by following the systematic procedure outlined on the analysis sheet than he will if he conducts his analysis haphazardly.

As the analysis is made, the facts that are learned and the suggestions for improvement that occur should be noted on the analysis sheet. The manner in which these notations are made is important. The analysis sheet serves the dual purpose of acting as an aid to clear analysis and later on of furnishing a record of the conditions in effect at the time of the analysis and of the changes suggested and made. Therefore, the analysis sheet should be filled in completely with clear descriptions of the various points considered. The descriptions should be sufficiently explicit to enable anyone who consults the analysis sheet to understand what the job is and what was decided in connection with each point considered. At the same time, in order to avoid overelaboration and an accompanying waste of time and effort, the descriptions should be concise. Either too brief or too lengthy descriptions are undesirable. The analyst will learn with practice to fill out his analysis sheets with a minimum of effort and a maximum of clearness.

Example of Filled-in Analysis Sheet.—Figures 42 and 43 show the front and back of an analysis sheet covering a simple milling-machine operation. The operation consists of milling a slot in a solid brass casting. The analysis sheet and the job are first fully identified. The sheet is dated, and information regarding the department where the operation is performed, drawing and pattern numbers of the part, name of the part, name of the oper-

Date Oct. 16, 1936 Dept. Small Machining Dwg 822304 Sub. 2
Mould .... Die .... Style .... Item 4
Pattern 8191-A Ins. Spec. .... L. Spec. .... Sub. ....
Part Description Clamp for Type XK Regulator Shaft

Operation Mill Slot Operator Jones

DETERMINE AND DESCRIBE	DETAILS OF ANALYSIS
1. PURPOSE OF OPERATION To mill slot in casting. Slot fits Regulator Shaft - Dwg 122301	Can purpose be accomplished better otherwise?
2. COMPLETE LIST OF ALL OPERATIONS PERFORMED ON PART No. / Description / Work Sta. / Dept. 1. Make Casting — Foundry 2. Mill Slot — Small Milling Machines — Small Machining 3. Drill two Holes — Sensitive Drill Press — Small Machining 4. 5. 6. 7. 8. 9. 10.	Can opra. being analyzed be eliminated? be combined with another? be performed during idle period of another? Is sequence of oprns. best possible? Should oprn. be done in another dept. to save cost or handling?
3. INSPECTION REQUIREMENTS a—Of previous oprn. Casting must be filled out completely and have no porous spots, rough spots, or burned in sand. b—Of this oprn. ±.002". This tolerance unnecessarily close for purpose. Checked with Schauer advisability of changing to ±.005". Will advise 10/14/36. OK Changed 10/19 c—Of next oprn. Holes must be properly located and to drawing dimensions.	Are tolerance, allowance, finish and other requirements necessary? too costly? suitable to purpose?
4. MATERIAL Common Brass. OK. Brass must be used to avoid rusting. Alloy specified is inexpensive and easily machined Cutting compounds and other supply materials None	Consider size, suitability, straightness, and condition. Can cheaper material be substituted?
5. MATERIAL HANDLING a—Brought by Conveyor b—Removed by Conveyor c—Handled at work station by Operator by hand	Should crane, gravity conveyors, totepans, or special trucks be used? Consider layout with respect to distance moved.
6. SET-UP (Accompany description with sketches if necessary) Standard vise is bolted to machine table with two bolts. Totepan is placed on floor to left of machine. Empty totepan to receive machined parts is placed on floor to right of machine. a—Tool Equipment Present Standard vise. 6" spl. side cutter T-807 Suggestions Use vise with quick acting clamp — Adopted 10/20 Provide ejector for removing part from vise — Adopted 10/20	How are dwgs. and tools secured? Can set-up be improved? Trial pieces. Machine Adjustments. **Tools** Suitable? Provided? Ratchet Tools Power Tools Spl. Purpose Tools Jigs, Vises Special Clamps Fixtures Multiple Duplicate

FIG. 42.—Analysis sheet for the analysis of a milling-machine operation—front.

7. CONSIDER THE FOLLOWING POSSIBILITIES. — **RECOMMENDED ACTION**

1. Install gravity delivery chutes. Adopted 10/20 Recommended to Riley 10/16 — Yes-from vise to tote pan
2. Use drop delivery. — Not necessary
3. Compare methods if more than one operator is working on same job. — Only one operator
4. Provide correct chair for operator. Adopted 10/20 — Must stand to operate 2 machines
5. Improve jigs or fixtures by providing ejectors, quick-acting clamps, etc. Recommended to Frank 10/16 — Yes-See Tool Suggestions
6. Use foot operated mechanisms. — Can operate air hose by foot if nec.
7. Arrange for two handed operation. — Not practical
8. Arrange tools and parts within normal working area. Adopted 10/20 — Operator instructed
9. Change layout to eliminate back tracking and to permit coupling of machines. Recommended to Riley 10/16 — Yes
10. Utilize all improvements developed for other jobs. — Done.

8. WORKING CONDITIONS

Satisfactory

a—Other Conditions Quantities have recently increased to 50,000 per order, thus justifying suggested more elaborate set-up.

Light
Heat
Ventilation, Fumes
Drinking Fountains
Wash Rooms
Safety Aspects
Design of Part
Clerical Work Required (to fill out time cards, etc.)
Probability of Delays
Probable Mfg. Quantities

9. METHOD OF PROCEDURE (Accompany with sketches or Process Charts if necessary)

a—Before Analysis and Motion Study.

Pick up small part from table
Place in vise
Tighten vise
Start machine
Run table forward 4"
Engage feed
Mill slot
Stop machine
Return table 6"
Release vise
Lay part aside in tote pan
Brush vise

b—After Analysis and Motion Study

Machine #1	Machine #2
Pick up small part from table Place in vise Tighten vise Start machine Run table forward 4" Engage feed Turn to machine #2	Mill slot
Mill slot	Turn from machine #1 Return table 6" Stop machine Open vise (part ejected aside) Brush vise Pick up small part from table Place in vise Tighten vise Start machine Run table forward 4" Engage feed Turn to machine #1
Turn from machine #2 Return table 6" Stop machine Open vise (part ejected aside) Brush vise	Mill slot

Arrangement of Work Area
Placement of
Tools.
Materials.
Supplies.
Working Posture
Does method follow Laws of Motion Economy?
Are lowest classes of movements used?

Saving .0080 × .55 × 250,000 = $1100.00 per year

See Supplementary Report Entitled Man and Machine Process Chart for Mill Slot Opern.
Date 10/22/36

OBSERVER A. Kennedy APPROVED BY

FIG. 43.—Analysis sheet for the analysis of a milling-machine operation—back.

ation, and name of the operator are all recorded. The analysis proper then begins.

First, the purpose of the operation is ascertained. The analyst learns that a solid casting is to be made into a clamp. It must be cut away to fit the part it is to hold. Thus, the purpose of the operation is to mill a slot, and it is a necessary operation. He considers various other ways a slot might be made. A cast slot would not be accurate enough. A die casting might do; but the same blanks are milled out to various sizes, and the cost of providing dies for the different sizes would not be offset by the saving made. Hence, the purpose of the operation seems best accomplished by milling.

When this decision is reached, item 1 is filled in. The purpose of the operation is described as "to mill slot in casting." This answers the purpose, but an additional note "slot fits regulator shaft Dwg. 122301" gives further information which may be useful later on.

Item 2, in this case, is comparatively simple to fill in. There are only three operations performed on the part from the time the casting is made until it is ready for the assembly. The analyst lists them, showing the work stations and departments where they are performed. His mental process will then be something as follows. He asks himself the questions listed in the column on the right of the sheet under the heading "Details of Analysis." The operations are quite dissimilar, and the sequence is seen to be proper. One possibility for improvement occurs, namely, that the drill-press operation might be performed by the operator on one part while the milling machine is making a cut under power feed on another. This, however, would necessitate moving a drill press beside the milling machine. Since there are a number of milling machines in the department and since the job is likely to be done upon any one of them, a drill press would have to be set up by every milling machine or else the production-control system would have to be changed to route the clamp job to a particular machine near which the drill press could be located. Neither plan appears practical under existing conditions, and the analyst decides to shelve this suggestion. He does not abandon the idea altogether but makes a mental note to watch for other jobs on which there are similar possibilities to see if one or two machine groups consisting of a milling machine and a drill press might sometime be justified.

With item 2 covered, the next step is to ascertain the inspection requirements of the job. The inspection requirements of the foundry operation are not difficult to write, for they are standard for all castings. The analyst, therefore, turns his attention to the requirements of the mill-slot operation. He finds that the dimensions of the slot must be held to within plus or minus 0.002 inch of the drawing dimensions and that the slot must be free from tool marks. For his own satisfaction, he investigates the use of the clamp in the finished apparatus to discover whether these requirements are necessary. After consulting the drawing of the shaft which the clamp is to hold and learning the tolerance to which it is machined, he examines an assembly to learn how the parts function. As a result of this careful check, he decides that the inspection requirements with respect to the size of the slot are more accurate than is necessary and that an allowance of plus or minus 0.005 inch will be close enough for satisfactory performance. The wider tolerance will make it somewhat easier for the operator to set up and run his machine, and it will also effect a slight saving in grinding cutters in the toolroom. When the decision has been reached, the analyst records it on the analysis sheet.

Merely noting the possibility of making an improvement will be of little value. The suggestion must be presented to someone who has the authority to take action upon it—in this case, the design engineer or the chief inspector—and the matter must be followed up until definite action is taken. Many otherwise capable analysts fall down at this point. They conceive worthwhile suggestions for improvement, but they fail to follow them up aggressively enough to secure action. Changes are not made in industry any more easily than elsewhere, for human nature is much the same in all walks of life. If conditions that have been in existence for a number of weeks, months, or years without giving any apparent trouble are attacked, the tendency is to let well enough alone and not to bother with a change. All progressive supervisors in industry know how difficult it is to get changes made when the change affects the work of someone else.

In the case under consideration, the suggestion for changing tolerances may be presented either at the time it is conceived or when the entire analysis has been completed. When the suggestion has been made, a note showing to whom it was offered should be recorded on the analysis sheet. If possible, the promise

of a date when a definite decision will be made should be secured and noted.

This procedure should be followed in the case of every suggestion offered. When action is taken, a further note should be made. The analysis sheet will then show the status of the job at any time. It will show the suggestions which were made, those which were accepted or rejected, and those which are still awaiting action. If the analysis sheet is not filed away until all suggestions have been acted upon, it will serve as a reminder to keep pushing those which are lagging and will insure that none is left unsettled.

This definite, systematic follow-up accomplishes two worthwhile results. In the first place, it insures that no suggestion of merit will be neglected through oversight. Secondly, because follow-up action is required, it insures that few impractical, half-worked-out suggestions will be offered. The analyst will soon learn not to waste his energies on the "I've often thought of it but haven't had time to do anything about it" type of suggestion. A man whose conversation abounds with hazy ideas of this nature is in need of a mental housecleaning, and nothing will give it to him like a clean-cut follow-up plan religiously adhered to.

On the analysis-sheet example, the action that was taken with regard to increasing the slot tolerances is clearly shown. When it was decided that present tolerances were too close, the matter was taken up with a man named Schauer. He promised a definite decision on Oct. 19. A longhand note shows that on that day the suggestion was accepted and the inspection requirements changed.

The description of the material of which the clamp is made is a good example of brief, clear phrasing. When the suitability of the material was investigated, it was found to be satisfactory in every respect. The easiest thing to do would be to make a note "O.K." and let it go at that. This, however, would not satisfy one who might have occasion to restudy the job at some future time, and a duplicate investigation would be made. To avoid this, the reason that the material is satisfactory should be stated. A noncorroding material must be used to avoid rusting which is likely to occur under the conditions under which the apparatus operates. Common brass will not rust. In addition, it is inexpensive and easy to machine. Therefore, it is well

suited to the requirements of the job. The brief description makes this clear. An elaborate write-up describing service conditions, the chemical analysis of common brass, and the relative machinability of various nonferrous alloys could do no more.

When the problem of handling material has previously been studied for the department as a whole, little need be recorded on the analysis sheet under the head of "Material Handling" with regard to the manner in which the material is brought to and removed from the workplace but a word or two describing the methods in effect at the time the analysis was made. If, however, in a certain plant or department, the first formal analysis which is made of material-handling methods on a single job reveals the fact that the general material-handling situation should be improved, the analysis of the single job will probably be temporarily abandoned, and a study of handling will be commenced. After a standard material-handling procedure has been worked out, the job analysis will again be taken up. A few words on the analysis sheet will serve to describe the standard system that has been evolved.

If a single job has large activity, a study of the material-handling problem for that job only may be justified, particularly if little attention has been paid to the matter before. Usually, on active work some study will have been given to material handling; for if a system is haphazard or inefficient on repetitive work, the piling up of material will soon bring the problem to the attention of the management. Therefore, most material-handling procedures on repetitive work will be found to be workable when examined. This does not mean, however, that they cannot be improved when analyzed with the idea of reducing to a minimum the effort necessary to move material. On the contrary, even where conveyer systems have been installed, it will often be found that changes can be proposed that will bring the material to the operators more conveniently and eliminate useless motions on their part.

A good example of this was encountered in the shipping department of a large industrial plant. Conveyers were used to bring material to the packers and to remove the packed cartons. They were located in such a position, however, that it was necessary for the packer to take a total of 20 steps during the course of packing a single carton. Relocation of the conveyers eliminated

this and increased production 20 per cent, at the same time materially reducing fatigue.

The procedure used for handling material at the work station should be examined on each job analyzed. A detailed consideration of the motions used to handle the material properly belongs

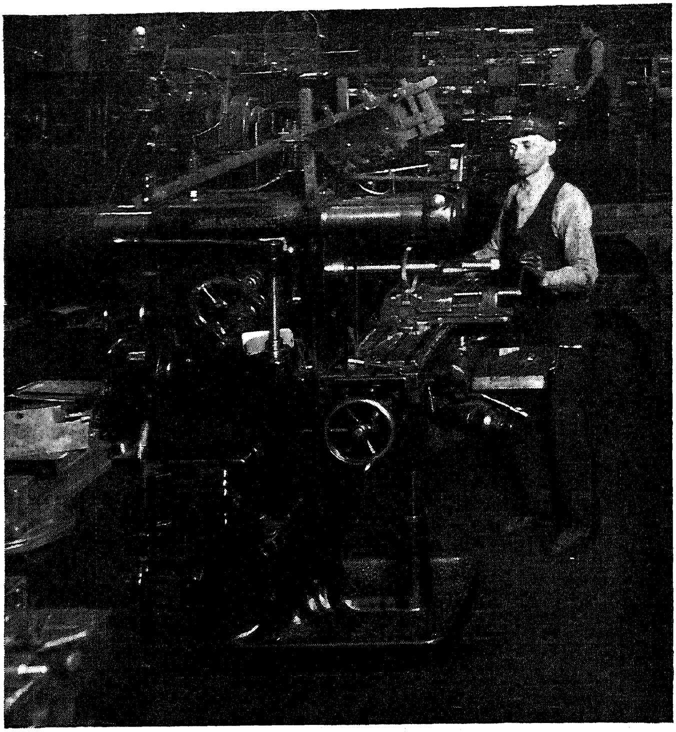


FIG. 44.—Photograph illustrating setup for milling machine operation.

under the heading of motion study. The larger aspects of the problem, however, should be investigated at the time item 5 is analyzed. If the material is handled by hand, the possibility of handling it more effectively by a mechanical means should be considered. If a mechanical device is used, it should be the best available for the purpose. When the best general method of handling material at the work station has been decided upon, a few words describing it should be recorded on the analysis sheet.

Under the head of "Setup," a description is given of the workplace layout and the arrangement of tools, fixtures, and so on. This description may be written if the setup is simple, but a photograph will be found more useful and infinitely clearer if the arrangement is at all complex. It would require several hundred words, for example, to describe the workplace layout pictured in Fig. 44, and even then it would be difficult to visualize the layout in its entirety. The picture tells the story at a glance and shows clearly the arrangement of the workplace at the time of the analysis.

When the machine setup is being considered, the tool equipment also is examined. The tools and the setup are so closely related that it is difficult to separate them, and nothing is gained by attempting to do so. In examining the setup of the milling machine, it is noted at once that a standard vise and a special side cutter are used. A description of these items of tool equipment is therefore recorded. Often, when tool equipment is examined with thoughts of job improvement uppermost in mind, suggestions for improving the tool equipment will immediately occur to the analyst. These should be recorded as they arise, even though they may reoccur during the consideration of items 7 and 9. It is better to duplicate the small amount of writing involved than to risk the possibility of overlooking a good idea.

The recommended action on the 10 possibilities for improvement listed under item 7 should not be filled in too hurriedly. It is all too easy to run over the list rapidly and to form opinions as to the practicability of each possibility on the basis of snap judgment. This should be avoided. The 10 points are listed because one or more of them will usually be found applicable to nearly every job analyzed.

In the example, it was seen that a gravity delivery chute would transport the finished part from the vise to the tote pan without a motion on the part of the operator. The clamp, of course, must be moved from the vise to the chute, but the desirability of an automatic ejector had already been discovered when analyzing the setup. Hence, it was recommended to Riley that a simple chute be provided. A note shows that the change was made the following day.

This arrangement, of course, makes drop delivery unnecessary, and a note is recorded to that effect.

Since only one operator works on this job, the note covering the third possibility, "compare methods if more than one operator is working on same job," is self-explanatory. The point is of paramount importance, however, and is one that was stressed repeatedly by F. W. Taylor. At a meeting of the American Society of Mechanical Engineers in 1910, Taylor said:

> . . . owing to the fact that the workmen in all of our trades have been taught the details of their work by observation on those immediately around them, there are many different ways in common use for doing the same thing, perhaps forty, fifty, or a hundred ways of doing each act in each trade, and for the same reason there is a great variety in the implements used for each class of work. Now, among the various methods and implements used in each element of each trade there is always one method and one implement which is quicker and better than any of the rest. And this one best method and best implement can only be discovered or developed through a scientific study and analysis of all of the methods and implements in use, together with accurate, minute, motion and time study.

Procedures for operator training, to be sure, have improved since the time this statement was made; and yet today, wherever detailed methods studies and detailed methods instruction have not been undertaken, it is the rule rather than the exception to find every operator on a given job using a different method. The methods may appear the same to the untrained observer who has not taught himself truly to observe; but careful analysis will reveal many differences, which, although they may individually be minor, in total cause a wide difference in output.

It is seldom that the close study of a number of operators on the same job will reveal the best method of doing the job as an already developed whole. Probably even a synthesis of the best methods in use on each element of the job will not do this. The analysis will, however, put the analyst in possession of a knowledge of the best-known methods for doing the work and will enable him to proceed with his developments without going over ground that has already been covered.

Possibility 4 under item 7 deals with the correct chair for the operation. If the operation must be done standing, a note to this effect is all that is required. If the operation is done sitting or partly sitting and partly standing, the matter of providing a proper chair should be considered carefully, and when a decision

has been reached the necessary recommendations should be made and recorded on the analysis sheet.

Possibility 5 suggests providing a vise with both a quick-acting clamp and an ejector. The advisability of using these labor-saving devices was recognized under item 6, although a less capable analyst might easily have overlooked them.

Under possibility 6, the fact that a foot-operated air hose could be provided for blowing chips out of the vise is recognized. This, however, would tend to make the setup somewhat special which should be avoided where possible on miscellaneous work. By this time, the analyst has a good idea of how he is going to improve the job, and he foresees that the foot-operated air hose may be an unnecessary refinement. Therefore, he records the possibility but postpones definite recommendation until later.

"Two-handed operation," possibility 7, is an abbreviated term used to describe an operation performed by means of motions of the arms made simultaneously in opposite directions over symmetrical paths. This is a highly effective arrangement where practical but cannot very well be used on the job being analyzed. The analyst, therefore, records "not practical" opposite this possibility. This is dangerously easy to write if job analysis is allowed to become a routine procedure, and the analyst must be very sure that he does not fall into the habit of deciding too quickly that two-handed operation cannot be attained. It is seldom easy to set up a two-handed workplace layout, for considerable detailed study is involved. Therefore, it is usually wise in any case of uncertainty as to the absolute impracticability of two-handed operation to make a note "determine after motion study" and then reconsider the point later on when the detailed motions used in doing the work have been more fully studied.

Tools and material should always be arranged within what is known as the "normal working area,"[1] but they seldom are if the arrangement is left to the operator. A rearrangement can usually quickly be made; and if the reasons for the rearrangement are carefully explained to the operator, he will probably adhere to it on future jobs even when instruction sheets are not provided.

On machine work where the machine works part of the time under power feed, it is often possible to give the operator another

[1] See Chap. XVI, page 203.

machine to run. The second machine may be set up for the same job as the first, or it may be set up for a different job if the handling and machining times are nearly the same as those for the first job. The job under analysis is ideal for this kind of setup. The part-handling elements consume somewhat more time than the machining element, but the suggested improvements will reduce the part-handling time until it is less than the machining time. The analyst, of course, has had this improvement in mind from the start. Being experienced, he recognized the fact that the foot-operated air hose would only add to the operator's idle time once the other improvements had been made and that, since this was not necessary for overcoming the effects of fatigue, there was no reason for providing the air hose.

In describing working conditions, it would be possible to go into great detail. The working conditions, however, in most modern shops are practically the same in all parts of a given department. Hence, considerable repetition will be involved if conditions are described completely for every job analyzed. A worth-while saving in time will be effected and a better description will be given if a report describing conditions in detail is prepared and kept on file. Reference may be made to it on the analysis sheet, and duplication of effort will thus be avoided. Any unusual conditions will, of course, be recorded on the analysis sheet. Any permanent changes that affect working conditions such as the installation of an improved lighting system should be described in a dated addition to the general report. This procedure will make it possible to check the conditions in effect at the time that any job analysis was made.

The conditions that apply only to the job being analyzed are recorded briefly under the subheading of "other conditions" under item 8.

Under item 9, the method being followed at the time the analysis is made is recorded. If several methods are in use, they should all be listed. If there is not room for this on the analysis sheet, a supplementary report should be prepared. The method at this point may usually best be described in terms of the elements of the operation. This does not give so detailed a description as an operator process chart showing every motion made by both hands, but the preparation of such a chart requires some time and is not always justified by the activity of the job.

If the activity is sufficient to warrant careful motion study, the chart will be made and will compose part of the supplementary report that should be attached to the analysis sheet.

A description of the method by listing the elements of the job is sufficient to give a good idea of how the job was performed. Indeed, many written instruction sheets consist of nothing more than a list of elements. Thus, although it is recognized that a list of elements is far from being a complete description of any method, it is also recognized that this is all that it is practical to give in many cases.

The description of the method after motion and time study may also be given in terms of elements. Reference to the example shows that a clear idea of the changes that were made in the method is thus obtained in comparatively few words.

The Analysis Sheet as a Supervisory Aid.—The analysis sheet was originally developed by the Methods Engineering Council for the use of methods engineers. Its use has since been greatly extended, and it has been found to be especially valuable to those who must supervise the work of methods engineers.

The value of the analysis sheet as a guide to systematic analysis has been pointed out several times. Before the sheet was available, methods-engineering supervisors did their best to insure thorough work on the part of their men by carefully instructing them in regard to the points they should consider and by cautioning them repeatedly to overlook nothing. There was no way of determining if instructions were being followed, however, unless the supervisor selected a job from time to time and questioned his engineer about it in great detail. In effect, he was forced to ask all the questions that he wished the methods engineer to ask to ascertain if they had been asked and answered. This, of course, meant duplicate work, but there was no other way.

The use of the analysis sheet changes this situation entirely. The supervisor, or for that matter any interested executive, can ask for the analysis sheet and accompanying reports, if any, for any operation he may wish to check. A brief review of the sheet will tell the story of the operation and of the analysis of the operation in a very short time. Hence, the analysis sheet, aside from its other important uses, is seen to be a valuable supervisory tool.

General Use of the Analysis Sheet.—The use of the analysis sheet need not be restricted to methods engineers. After a careful explanation of its use, it can be filled in by almost any shopman of average intelligence. It is true, of course, that the analysis sheet will be filled in completely and satisfactorily from the methods engineer's point of view only by a trained analyst well grounded in the principles of motion and time study.

At the same time, it is not necessary that the analysis be made complete to the last detail for it to bring about worth-while results. The act of attempting to fill in the sheet causes one to look at a job in its details. A job is seen to be a series of simple problems instead of a single complex problem, and solutions to these problems are found to be comparatively simple when considered individually. The analytical approach is encouraged, and guidance is given through each step of the study.

Thus, the analysis sheet can be a help to shop supervisors other than the methods engineer in studying and improving the work that comes under their jurisdiction. The foreman, for example, does not need to rely altogether on the work of the methods engineer for reducing operating costs and setting up improved methods. He can select any job that seems to offer possibilities, analyze it with the aid of the analysis sheet as he has time, and nine times out of ten discover a better way of doing the job if it has not been previously analyzed by this method.

In other words, the manner of using one of the most potent tools of the methods engineer, namely, operation analysis, is shown by the analysis sheet. Different men will use it with varying success depending upon their experience and ability. Nearly anyone, however, can accomplish something, if he conscientiously tries to make an analysis in the manner outlined on the analysis sheet.

The authors have given the sheet to foremen, tool designers, production men, cost accountants, and so on, and have asked them to select a job, analyze it, and fill in the sheet. In the majority of cases, the filled-in sheets contain worth-while suggestions for improvement. With these experiences in mind, therefore, the hope is expressed that a wide use will be made of the analysis sheet or some similar analytical guide. For example, the key supervisors of a given plant might each be required to

analyze one operation coming under their jurisdiction every week and to fill in an analysis sheet. This would unquestionably bring out meritorious suggestions for improvement, and the assembled analysis sheets might form the basis for lively discussions at subsequent supervisors' meetings. There are many worth-while programs that can be inaugurated to suit individual plant conditions. Results in all cases, however, arise from the same source, that is, the stimulation to analytical thought that such a procedure provides.

CHAPTER XI

OPERATION ANALYSIS—PURPOSE OF OPERATION

In beginning the analysis of any industrial operation, the very first point that should be considered is the purpose of the operation. Why is the operation being performed? To the nonindustrialist who is accustomed to hearing about the efficiency of modern industry, it may seem strange that the methods engineer considers it necessary to ask such a question. It assumes apparently that industry does work which is unnecessary and in effect pays out money for which it receives nothing in return.

Unlikely as this may seem to the layman, the condition actually exists. Operations are performed day in and day out that are either absolutely unnecessary or can be performed much more effectively in some other way. This is as true of repetitive operations upon standardized products as it is of nonrepetitive operations on special or jobbing work. In a number of instances where the authors have directed detailed studies of the operations performed on mass-production jobs, they have found that from 10 to 35 per cent of the operations were unnecessary.

In view of this experience, therefore, the logical point at which to begin an operation study lies in a consideration of the purpose of the operation.

Unnecessary Operations in Industry.—The reasons that unnecessary operations are performed in industry are several. In the first place, even the most standardized product at one time passed through the development stage. At the outset, the designer was the only one in all probability who thoroughly understood the product. When manufacture was begun, he had to tell the shop what was wanted through the medium of drawings and written and verbal instructions. This is not easy to do. No matter how clearly information is prepared, there are always questions that arise. Every designer has been called upon again and again to explain points that are clearly portrayed on his drawings. It requires a definite period of cutting and trying and developing before all the so-called "bugs" are worked out.

During this development stage, the operations by which the product is to be made are being devised. The operations are performed on a sort of hand-to-mouth basis; that is, one operation is performed before the next is considered. Even if an attempt is made to lay out in advance the proper sequence of operations on new work in the planning or methods department, difficulties are likely to develop in the shop that make changes necessary. The design may be changed, or the material, or the operations themselves as trouble is encountered.

As a result of this development condition, it is small wonder that the process is finally set up with certain unnecessary operations. These operations may have seemed necessary at one time, but owing to changes or development they are no longer necessary. Nevertheless, they are performed and are likely to continue in effect until, after the process has been reduced to a standard routine, someone with the questioning attitude comes along and begins an investigation.

After the initial-development state has been passed, manufacturing troubles are by no means over. A process may run smoothly for a number of months, and then suddenly a difficulty is encountered. The difficulty, of course, must be corrected immediately, and it is often much quicker to add an extra operation than to investigate the causes of the difficulty. If the operation corrects or seemingly corrects the difficulty, it soon becomes a standard operation, even if the causes of the difficulty disappear or are otherwise eliminated, and thus another unnecessary operation is born.

The difficulties referred to may be several. A shipment of poor or improperly prepared material may cause difficulties that can be eliminated only by extra work. The extra work may develop into a standard operation, even though good material is received in the future. If the product is an assembly, it may suddenly start to function improperly on test. If it is at all complicated, it may be difficult to determine just what the causes of the unsatisfactory performance are. Extra operations are added to overcome this or that supposed difficulty. When the product begins to function again, it is not always clear which operation corrected the difficulty and some or all are retained.

Those who are responsible for setting up manufacturing processes are no more infallible than other men. In the judgment

of a certain individual, an operation may seem necessary, and he orders it to be performed. Regardless of the soundness of his judgment, the operation will continue to be performed until someone proves it to be unnecessary.

Again, certain operations are performed because of the snap judgment of someone who has the authority to enforce his decisions. Again and again, operations are discovered that are performed because an executive of the company in walking through the shop saw something of which he did not approve and at once issued orders that were followed ever since. When various department heads meet to consider a customer's complaint that may seem serious at the time, extra work may be insisted upon by the sales department and agreed to by the manufacturing department for reasons of policy. The cases of unnecessary work caused in this way are too numerous to attempt to list completely.

In the final analysis, unnecessary operations are due primarily to a lack of thorough investigation at the time the operations are first set up or to a natural inertia or an oversight that keeps operations in effect after changes have rendered them unnecessary. Detailed, searching analysis is needed to reveal these conditions, and it is this kind of investigation that methods studies bring about. It should be recognized, of course, that operations rendered unnecessary by new developments, inventions, improved machinery, and the like, are not being referred to here.

Questions.—It is important to consider the purpose of the operation, but the mere question "What is the purpose of the operation?", mentally framed, may not be suggestive enough to develop a thorough understanding of the matter. If one approaches the supervisor in charge of the operation and asks the question, one will get an answer, of course, and usually the answer will appear logical on the surface. It is not until one begins to search and probe more deeply that the real answer is obtained. For this reason, questions similar to those contained in the following list should be asked. Further, they should be answered only after mature consideration, if the true answer is to be obtained.

1. What is the purpose of the operation?
2. Is the result accomplished by the operation necessary?

3. If so, what makes it necessary?
4. Was the operation established to correct a difficulty experienced in the final assembly?
5. If so, did it really correct it?
6. Is the operation necessary because of the improper performance of a previous operation?
7. Was the operation established to correct a condition that has since been corrected otherwise?
8. If the operation is done to improve appearance, is the added cost justified by added salability?
9. Can the purpose of the operation be accomplished better in any other way?
10. Can the supplier of the material perform the operation more economically?

Typical Answers.—In a plant manufacturing frames for automobiles, the last operation before painting consisted of reaming certain holes which had previously been punched in the frame. Two operators equipped with air-driven reamers stood at the end of the assembly line and reamed the holes as the frames passed them on a chain conveyer. It was a full-time job for both men and had been for several months.

During the course of a study of frame-manufacturing methods, the purpose of this operation was questioned. The thought at first was that it might be possible to punch the holes sufficiently closely to size to eliminate the reaming operation. Reference to the drawing, however, showed that the customer demanded reamed holes.

It would have been natural, perhaps, to consider that the question "Is the operation necessary?" was satisfactorily answered by the drawing. One of the methods engineers in the plant, however, realized the danger of accepting the first answer that came to hand and decided to investigate more thoroughly. He went out on the plant parking lot and located a car of the model that used the frame in question. To find the ultimate purpose of the reaming operation, he crawled underneath the car to see what the holes were used for and discovered that they were not used at all. Obviously, then, not only the reaming but also the punching of the holes was unnecessary.

Subsequent investigation showed that at one time an engineering change in the construction of the frame had been made

which eliminated the use of the holes. Through an oversight, the drawing was not changed, and the reaming operation continued until the time of the investigation.

This incident, besides confirming the fact that errors are made in connection with manufacturing information, illustrates two important points. In the first place, it shows the necessity of constantly questioning the purpose of operations. The reaming operation was performed day after day for a number of months. It would be entirely natural to assume that the operation was necessary just because it had been done so long. Unless a man is trained to question every factor connected with the manufacturing process he is studying, he is likely to accept familiar operations as necessary and to concentrate upon better tools or methods for doing the operations, rather than to attack them from a more fundamental viewpoint.

In the second place, the case illustrates the necessity of applying the questioning attitude with a real desire to get at the bottom of the matter. The asking of a question will nearly always bring forth an answer. The first answer is quite likely to be superficial, however, and more thorough probing is necessary to learn the real facts. Hence, repeated questioning is necessary.

For example, the first question in the above list is "What is the purpose of the operation?" Asked in connection with the reaming operation, the answer is "To make the holes a certain specific size." This might seem to be an answer, but the trained analyst would follow up with the second question on the list, "Is the result accomplished by the operation necessary?" Reference to the drawing apparently evokes an answer in the affirmative. The basic reason for performing the operation is still not clear, however, so the analyst asks the third question, "If so, what makes it necessary?" His investigation to determine the answer to this question finally uncovers the fact that the operation is absolutely needless.

For many years, it was the practice to polish the edges of the glass windows that go in the doors of automobiles. The reason given was that a good appearance was desired. It is true that edge polishing improves the appearance of a window glass, but only when it is outside the car. When it is assembled, as it is when the customer sees it, only the top edge shows in most

designs of window. Hence, three-quarters of the edge-polishing operation is unnecessary. A smooth edge is required so that the window will not mar the channels in which it runs, but a polished edge is a refinement that is in no way justified. This fact was obvious as soon as it was pointed out, but until that time thousands of dollars were spent unnecessarily by a large manufacturer of automobile glass.

In the manufacture of an electric-clock motor, four small pinion shafts were pressed into a bakelite housing. The first shafts received from the supplier went in nicely. On subsequent shipments, however, difficulty was encountered. The shafts had a small burr on the end formed by the cutting-off tool. In order to use the shafts, it was necessary to add the operation "grind burrs."

This condition was taken up with the supplier by letter, but the supplier said that it was impossible to avoid the burr. There the matter rested until a methods study was made of the operation. Preliminary questioning brought out the above-mentioned story. The analyst, however, was not convinced that the shaft could not be produced without burrs. As a matter of fact, an investigation showed that a similar shaft used for the rotor of the motor was received from a different supplier without burrs. The first supplier was again asked if he could not furnish shafts without burrs, but he again answered in the negative. The analyst then suggested a change of suppliers. This was made, and shafts free from burrs were received thereafter. The first supplier had been too indifferent to attempt to improve his product. The easiest thing to do was to correct the supplier's shortcomings by adding an extra operation. The correct procedure, however, was to persist until satisfactory material was obtained.

A certain metal article manufactured in large quantities required a label of directions. This label was stuck onto the outside of the article. During the course of a study of the product, it was learned that the label was pasted on with flour paste. Several labels were placed face down on a cloth. Paste was applied with a brush, after which the labels were stuck in place. The analyst questioned the use of paste. He was told that gummed labels had been suggested and undoubtedly would be supplied in the future. He examined the labels being used

at the time and found that they were coated with gum. Seven operators were engaged in applying paste to gummed labels.

This case illustrates the strength of habit and inertia. The original labels were ungummed. Therefore, paste had to be used. A suggestion was made that gummed labels be substituted. They were accordingly ordered and when the supply of ungummed labels was exhausted the gummed labels were issued. No one but the operators realized, probably, that the new labels had arrived, and they proceeded to apply paste as before either without thinking or in order to appear busy in a department that was facing part-time operation.

The stamping, for which the flow chart, Fig. 36 of Chap. VIII, was made, was formed in a series of punch-press operations. On a certain order, the first two operations were performed on about 5,000 pieces. A rush order for another part was then worked on. The 5,000 partly completed pieces remained in temporary storage in the punch-press department and during that time picked up considerable dirt, including particles from the rush job which was made of metal screen.

As a result, when the job was put back in work again, considerable difficulty was experienced on the third operation. The operator had to wipe each blank clean with a rag before he could put it in his press and, of course, could not meet the regular time allowance. He complained to the time-study engineer who arranged to have a boy wipe the parts clean. The operator could then go ahead without interruption.

About two months later, the time-study engineer found that the parts were still being wiped off between the second and third operations, although the particular dirty lot had long since been completed. When he asked why the operation was being performed, he was informed that he himself had authorized it. The operation was, of course, absolutely unnecessary on subsequent lots, but so strong is the reluctance to abandon an operation after it has once been performed that it was necessary for the time-study engineer specifically to authorize its discontinuance.

If an operation is necessary, it can sometimes be accomplished better in some other way. The pinions on the previously mentioned electric clock contained burrs which in this case could not be eliminated. They were removed by picking them off with a pointed instrument. Tumbling them in a tumbling barrel

removed the burrs equally satisfactorily at but a fraction of the former cost.

Occasionally, a consideration of a better way of accomplishing a certain purpose leads to a major design change. For example, the coils used in large turbo generators are made up of a number of turns of heavy strap copper. These are formed on a bending machine and form rectangles some 30 or 40 feet in perimeter. The last three turns of each coil have to be about 1/8 inch narrower than the other turns to fulfill insulation requirements. Formerly, it was the practice to remove the 1/8 inch of metal from the last three turns by hand filing, the equivalent of filing a strip of copper 120 feet long for each large coil. Thousands of hours were consumed on this work in the department making the coils. During the course of a methods study, the question was asked, "Can the purpose of the operation be accomplished better in any other way?" The operation was at length eliminated by a design change. The last three turns were made of narrower strap copper and joined to the heavier turns of the coil by a single brazed joint.

The battery cable discussed in Chap. IV was originally purchased in 200-foot lengths. It was made up into leads 49 inches long, and the first operation consisted of cutting the cable into 49-inch lengths. The operation was necessary, of course, but the suggestion was made that the manufacturer of the wire might have a better cutting-off method than the comparatively crude method then in use. Investigation showed that the wiremaking machine could be set to cut off the wire in 49-inch lengths as easily as in 200-foot lengths. Thus the cutoff operation was eliminated, and the wire was obtained in 49-inch lengths at no additional cost.

Eliminating Operations.—The examples just given demonstrate the fact that many industrial operations can be eliminated if proper investigation is made. It is much easier to add an operation, however, than it is to eliminate one. Even after an operation has been shown to be unnecessary, it is not always easy to obtain its discontinuance. Habit is strong, and there is a natural tendency to resist change. If a process is working smoothly, there is a decided reluctance to abandon any part of it. It is common experience that operations that are added, almost one might say on the spur of the moment, can be discontinued only

after serious discussion on the part of a group of interested supervisors and usually only after someone in a fairly responsible position gives the order and accepts the responsibility.

Thereafter, for a time, the change is likely to be blamed for any difficulty that crops up whether there is any justification for it or not. This is a peculiar condition, perhaps, but one that any progressive shopman encounters again and again. Its existence should therefore be recognized. Resistance to change should be taken as a matter of course, and those who desire to make a change must be prepared to make an effort to get it adopted probably out of all proportion to the effort that would be required if human beings were not human beings.

At the same time, the man who prides himself upon being progressive must be careful that he does not adopt a similar attitude when changes are suggested in his own work that he himself does not initiate.

CHAPTER XII

OPERATION ANALYSIS—COMPLETE LIST OF ALL OPERATIONS PERFORMED ON PART

No operation can be safely studied by itself; it must be regarded as a part of a more or less complicated or extensive whole. The effect of any changes that are suggested must be considered in the light of the complete job. Only in this way can one be sure that the contemplated action will be truly worth while.

Item 2 on the analysis sheet provides space for listing all the operations performed on the part. The operation process chart, of course, shows the operations in their relation to one another much more clearly than a simple list, and if such a chart has been made up item 2 need be filled in only for the sake of completeness. If no chart has been constructed, then the filling in of item 2 insures that all operations performed on the part will be reviewed. The point to be emphasized is that a clear understanding of all steps of the process must be gained by the analyst, and whether he gains this understanding from an operation process chart or from item 2 of the analysis sheet will depend upon the nature of the job being studied.

Necessity for Reviewing All Operations.—If a detailed study is made of a single operation, the method of performing that operation can usually be improved. If, however, the operation can in some way be eliminated altogether or greatly simplified through some other change in the process, a far greater improvement will be made. These possibilities, major sweeping changes, can usually be seen by reviewing the process as a whole.

For example, a time-study engineer was requested to place a certain salvaging operation upon an incentive basis. A large number of parts had been scrapped, and the quantity involved was deemed sufficient to justify a time study. The operation for which a time allowance was requested consisted of removing a nut from a threaded casting. A girl performed the operation. She disassembled the nut and placed it in one tote pan and the threaded casting in another.

The time-study engineer did not fill out an analysis sheet in this case, but he mentally followed the steps of the analysis procedure. He decided that before making the time study he would investigate the operations subsequently performed on the part. Inquiry showed that the tote pans of nuts and the tote pans of threaded castings were trucked to the floor below. There they were both dumped into the same scrap bin. Hence, he saw at once that there was no reason for putting the disassembled parts into separate tote pans.

He next investigated what was done to the parts when they were removed from the scrap bins and learned that they were all put into a reclaiming furnace together and melted. It was self-evident that the nuts and threaded castings would melt as well

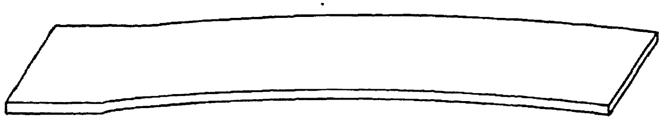


Fig. 45.—Copper segment formed to radius.

assembled as disassembled and that therefore the operation which he was requested to study was entirely unnecessary. He immediately had it discontinued which, of course, resulted in a much greater saving than would have been obtained by improving the motions used to perform the job and by placing it on an incentive basis.

The operation just described was, of course, only a temporary operation. It was set up hurriedly by someone who did not stop to consider the ultimate disposal of the parts. This might be accepted as the explanation of the ridiculous condition discovered if similar conditions were not frequently revealed in standard work performed year in and year out.

A rather striking example of such conditions occurred in a plant manufacturing large electrical apparatus. Certain copper segments were required to be bent to a radius as shown by Fig. 45. The operation was performed in the copper shop of this plant. The segments were first rough-bent on a bulldozer and then were formed by hand to the exact radius by a bench operation. This was a tedious, exacting operation and involved a good many man-hours per unit of finished apparatus.

The job was a standard job and was performed in this manner for a long period of time. Eventually, however, because of

competitive difficulties, a cost investigation was ordered. A methods engineer was assigned to the job and was requested to look for means of reducing costs. When he took up his consideration of the copper segments, he saw at once that the bench operation was costly. Before seeking a better means of forming the radius, however, he investigated the other operations performed on the part. As a result, he discovered the following situation.

The segments with their radii formed were transported to another department to have six round bars brazed to them. At the start of this operation, the brazer took a mallet and flattened the segments, thereby totally destroying the radius that had just been formed so expensively. After he had brazed the six bars in place, he bent the segments roughly to radius again and shipped them to the assembly floor. There they were assembled to the finished apparatus, and investigation showed that they functioned satisfactorily.

Further investigation showed that the situation had come about as follows. The copper segments when bolted in place on the finished apparatus formed a circle of large diameter. When the drawing of the segment had originally been prepared, the detail man in the engineering department had computed the radius and had recorded it on the drawing to two decimal places.

The copper shop interpreted the decimal places as meaning that an accurate job was required. Hence, they set up the operations that would give this accuracy. When the segments reached the brazer, he had difficulty in holding the six bars in place during brazing. The bars were round and the segments were formed to a small radius; quite naturally, the bars tended to roll out of position. The brazer was an experienced man, and he knew where the segments were used. He reasoned that since they made up a large circle, the small radius in each segment was relatively unimportant. He could do his own work easier if the segments were flat. Therefore, without saying anything to anyone, he proceeded to flatten them, braze on the bars, and roughly bend them again. The segments performed their function satisfactorily in the finished apparatus, and for months the condition existed as described. One department performed an expensive operation which the next department immediately

destroyed. Owing to the physical separation of the two departments, it required a thorough analysis and investigation to bring the condition to light.

Another situation that serves to emphasize the necessity of viewing a manufacturing process as a whole occurred in an automobile-body plant. The floor mats for a certain model of body were shipped in by an outside supplier. They were unloaded in a sub receiving area and were stacked on the floor. Each day enough floor mats to care for the day's production were removed from the pile and loaded on a truck. They were then trucked 150 feet to an elevator, carried up to the third floor, trucked about 100 feet to the assembly line, and unloaded.

As bodies came down the line, the floor mats were unpacked and placed in position in the bodies. As each body came off the line, it was taken over to the elevator, sent down to the first floor, and pushed about 150 feet to the point where it was to be packed for export shipment. The first operation consisted of bolting two skids to the body. In order to do this, the floor mats had to be removed. They were taken out of the body and placed on the floor beside the stock of floor mats from which they had been taken only a short time previously.

After this condition was pointed out, it was obvious that the floor mats should never have been sent to the assembly line, and the procedure was at once changed. The incident caused a search for similar conditions, and it was discovered that in order to attach the shipping skids the front seat also had to be removed. The seat was bolted in place on the assembly line only to be removed again shortly afterward in the shipping department. This procedure was also corrected.

Even when all operations are performed in the same department, similar conditions are sometimes found. They are more likely to occur, however, when the processing centers are widely separated, and although the complete list of operations should always be ascertained in any analysis this precaution is particularly important in cases of this kind.

Questions.—Typical questions that should be mentally framed and carefully answered while the operations of the entire process are being reviewed are as follows:

1. Can the operation being analyzed be eliminated by changing the procedure or the operations?

2. Can it be combined with another operation?
3. Can it be subdivided and the various parts added to other operations?
4. Can part of the operation be performed more effectively as a separate operation?
5. Can the operation being analyzed be performed during the idle period of another operation?
6. Is the sequence of operations the best possible?
7. Would changing the sequence affect this operation in any way?
8. Should this operation be done in another department to save cost or handling?
9. If several or all operations including the one being analyzed were performed under the group system of wage payment, would advantages accrue?
10. Should a more complete study of operations be made by means of an operation process chart?

Typical Answers.—The last operation of a certain manufacturing process consisted of stamping the number of the operator who made the final assembly. The purpose of the operation was to enable the foreman or the inspector to trace defective work back to the operator responsible. The operation was necessary because several operators worked on the assembly operation, although it was only a part-time job for each of them. The operation of stamping was eliminated by arranging the work so that only one operator performed the assembly operation. She was thus automatically responsible for all defective work, and there was no need of marking the parts.

There are numerous ways of eliminating operations. Tapping threads in some kinds of metal can be eliminated by using screws that cut their own threads as they are inserted. Drilled holes in castings are often replaced by cored holes. Layout operations can be eliminated by adding projections to the pattern that will cause center marks in the finished casting.

Operations can often be combined to good advantage. On punch-press work, two or more operations can sometimes be combined by improved die design. The same is true of machine work. Two milling-machine operations can be combined by improving setup, cutters, or fixtures. A good example of combining operations and one that offers possibilities in many

kinds of manufacture consists in combining drilling and tapping operations by using a special combined drill and tap as shown by Fig. 46. The combined drill and tap are inserted in the conventional self-reversing tapping head in the spindle of a drill press. Lowering the spindle brings the drill into action. When the hole is drilled, a further lowering of the spindle brings the tap into position.

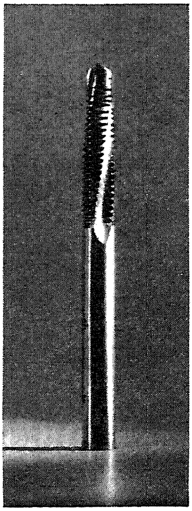


FIG. 46.—Combined drill and tap.

Sometimes, instead of attempting to combine operations, it is advantageous to split one complicated operation into two or more simple operations, an application of the familiar principle of the division of labor. For example, on a certain assembly operation, all assemblers were required to get their own material. Although all assemblies were of the same general nature, there were many variable or special items used on individual orders. Hence, it was rather difficult at times to interpret the order and to locate all needed material. Each operator spent considerable time away from her workplace, and there was a good deal of confusion and walking about in the department. The situation was much improved by dividing the operation into two operations, "interpret orders and gather material" and "assemble." One operator was assigned to the first operation and, because she had no other duties, soon became skilled at interpreting orders and locating the material necessary to fill them. She watched all incoming material and the special items that were being processed in the department and, as a result, was able to gather material for any given order with a minimum of searching. The assemblers were able to stay at their workplaces and concentrate on the assembly operation; hence, they too became more efficient.

Care must be taken not to subdivide a process too finely. If operations are made too short, the time spent in picking up a part and laying it aside may be greater than the saving made by specialization. Progressive assemblies such as that shown by Fig. 47 where each operator performs but a small part of the assembly are very efficient in certain types of work, particularly

where the product is large as in the case of automobile assemblies. On the particular operation shown by Fig. 47, however, a saving of 60 per cent was obtained by combining all assembly operations and having the entire operation performed under the setup shown by Fig. 48.

Many operations contain idle periods when the operator has nothing to do. On machine work, when the machine is making a cut under power feed, the operator often stands by in idleness, for no other work is provided. If he is given a vise, as shown in

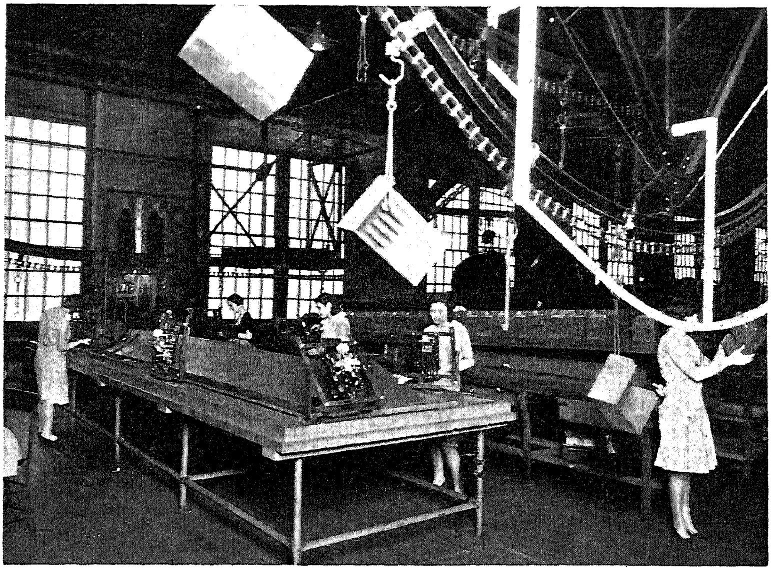


FIG. 47.—Progressive assembly line for five-horsepower cross-the-line starters.

Fig. 49, he can remove the burrs formed by his machining operation, and thus the operation "file burrs" is eliminated as a separate operation. An increasingly used application of this principle consists in giving the operator additional machines to run during the time when he would otherwise be idle. This will be discussed at some length later on.

On some kinds of sewing-machine work, idle periods occur when long straight sewing is done. Where the machine has complete control of the operation, another operation can often be performed. When parts have to be heated or cooled during a

process, the operator usually has idle time which may be utilized. In babbitting bearings, for example, where bearings are made in small quantities, the bearing shell is clamped to a mandrel and the babbitt is poured. After pouring, the babbitt must be allowed to solidify before the bearing can be removed from the mandrel. It is not uncommon to see the babbitter standing in idleness during this cooling period or at best hastening the process

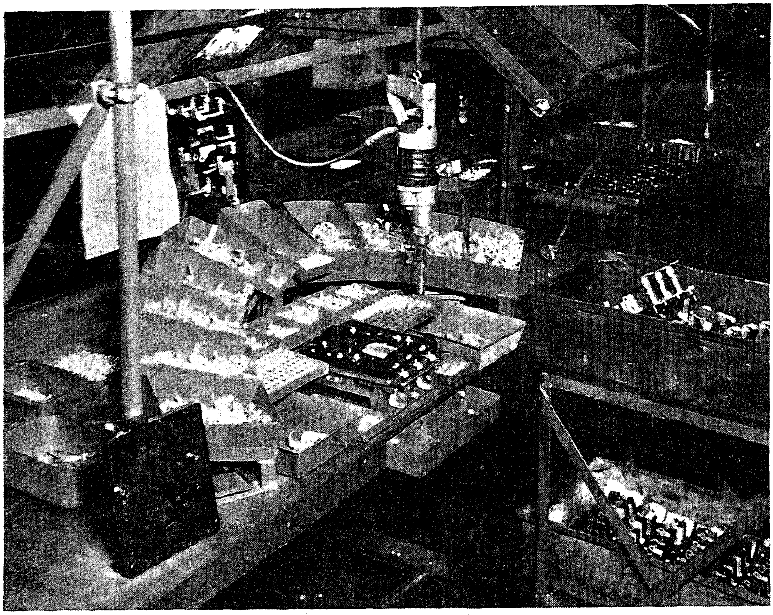


FIG. 48.—Unit assembly work station embodying principles of motion economy for five-horsepower cross-the-line starters—production increase 150 per cent.

by directing an air blast against the bearing shell. This time can better be employed in tinning bearings, removing risers from bearings previously poured, or preparing another bearing at another work station or in other useful ways.

The sequence of operations sometimes can be rearranged to yield advantages. In machine work, the sequence of several machining operations can often be varied. Usually, however, there is one sequence that is best from the standpoint of accuracy, ease of locating, and so on. Painting is commonly done as the final operation before packing. On many products, certain

machined surfaces must not be painted. Therefore, they must be carefully masked off during the painting process. This difficulty can sometimes be avoided by painting the unprocessed materials with a tough, durable paint as the first step of the process. The painting may be done quickly at that point as there are no surfaces to be protected. The unwanted paint is machined off during the subsequent operations. Any scratches

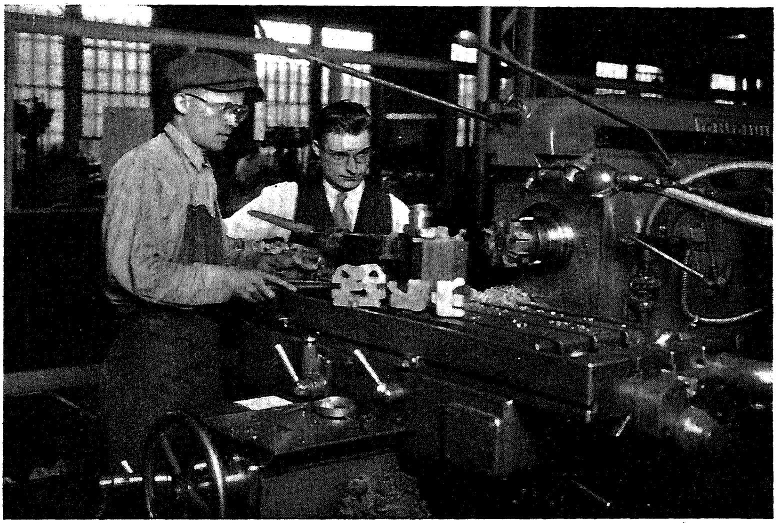


FIG. 49.—Milling machine equipped with vise permitting operator to remove burrs while machine is making cut.

or nicks appearing on the finished product may be rapidly touched up, and an over-all saving results.

In manufacturing plants where all of a certain kind of work is done in one department, considerable material handling is sometimes involved. For example, a plant manufacturing miscellaneous war material had a paint shop located on the first floor of a building near the shipping department. This was the best location from the standpoint of most products, for the natural flow of material was from the manufacturing buildings to the paint shop to the shipping department. One item, however, did not flow this way. It was manufactured on the third floor of another building. Then it was sent to the paint shop for

painting, after which it was returned to the floor it had just left for assembly to another item. The amount of travel in this case was large, and it was eliminated by providing a spray booth in the department in which the item was made.

A survey of the operations performed during a process may indicate that the time required to perform a certain operation will depend upon how well a previous operation was performed. In cases of this kind where there is a definite relation between operations, consideration should be given to setting up an arrangement whereby all operations are done by the same operator or group of operators. In the manufacture of the cooling unit for large ice-making machines, a number of tubes are bent into a sort of hairpin shape and assembled. The next operation consists of straightening any tubes that may be out of shape. The amount of straightening required depends upon how carefully the forming and assembling were done. If all operators work as individuals, the amount of straightening is large. When they work as a group, however, it is reduced to a minimum.

Conclusion.—The examples given illustrate the sort of improvements that are made when the operations performed during a process are considered in their relation to one another. The list could be greatly extended; but since the examples are intended to be illustrative and suggestive rather than instructions regarding the manner in which specific problems can be solved, it is felt that the list is sufficiently complete for the purpose. It should be noted, however, that the examples are not drawn from any one type of industry but come from a wide variety of products and processes.

CHAPTER XIII

OPERATION ANALYSIS—INSPECTION REQUIREMENTS

The inspection requirements or the standards of quality, accuracy, finish, and so on, that the operation must satisfy play an important part in the methods used to produce the part. In fact, in many cases, the requirements fix the method. The accuracy with which the diameter of a small shaft must be machined and the finish which the machined surface must possess will determine the machines that must be used, the number of cuts taken, and the feeds and speeds.

Hence, at the outset of any methods study, it is important, first, that the inspection requirements of the operation be known and, second, that these requirements be reviewed for correctness. Evident as this may be when due consideration is given to the importance of inspection requirements, the point is too often overlooked in everyday rate-setting work. The assumptions are made that the operator is doing a job which will pass inspection and that the requirements as specified by the designer or the chief inspector are correct. Undoubtedly these assumptions are true in the majority of industrial operations, but enough important exceptions are encountered to make an analysis of inspection requirements a point of primary importance.

Necessity for Fixed Inspection Standards.—Probably no one factor is more upsetting in a manufacturing organization than variable or elastic inspection requirements, and yet it is the exception rather than the rule to find a plant that sets up specific requirements and adheres to them strictly.

A large manufacturer of aircraft engines has the policy that a part must either conform to the drawing or be scrapped. There is no such thing as someone deciding that although a part is one-thousandth of an inch under the size specified on the drawing the error is not great enough to justify scrapping an expensive part. The company's attitude is that if the part which differs from the drawing is satisfactory then the drawing is wrong and

should be changed. In other words, the drawing must state correctly the necessary requirements for the job. If the part conforms to the drawing, it passes inspection; if not, it is scrapped definitely and without argument or discussion. The line of demarcation between good work and bad is sharply drawn and hence is clearly understood by everyone.

The difficulties encountered when no fixed policy is set up with regard to inspection standards are many, and they affect directly or indirectly everyone in the organization. If inspection requirements as set forth by drawings, manufacturing information, or process specifications are not rigidly adhered to, everyone in the organization considers it necessary to use his own judgment with regard to what is wanted, and no one has a definite basis on which to work. As a result, opinions differ as to what constitutes an acceptable job, disputes are many, and standardization is difficult if not impossible.

The work of the methods engineer is decidedly difficult where inspection requirements are elastic. In a certain plant, for example, inspection requirements were established by the engineering and inspection departments working together. Before any time studies were taken on new work, the time-study engineers were instructed by their supervisor first to learn what the inspection requirements were, which, of course, was the proper procedure. Because inspection standards were not rigidly adhered to in this plant, however, it was difficult to get a true statement of the proper requirements. The inspectors had given little consideration to methods-engineering work, and they reasoned to themselves that since the operations were to be done on an incentive basis the operators would slight quality in order to produce quantity. This is something that the inspectors themselves could control by rejecting work which did not come up to standard, but because the standards were elastic they had difficulties of their own, as will be seen presently, and hence they reasoned as shown above.

Believing that the operators would let up on accuracy and quality as soon as an incentive was established, the inspectors would tell the methods engineer that the inspection requirements were more severe than they actually were. They did this sincerely, feeling that they were acting in the best interests of the company. By setting the standards too high, they felt that the

slacking off which would come after the rate was set would result in the quality which they desired.

The methods engineers in this plant realized, of course, just how the inspectors reasoned. After seeing a few cases where the quality demanded at the time the study was made was not required after the rate was set, they felt that the information given by the inspectors was unreliable. They could not deliberately accuse the inspectors of stiffening the requirements every time a study was about to be made without causing serious trouble in the organization. Therefore, they said nothing but proceeded to discount the standards set forth by the inspector, and they came to rely more and more on their own judgment of what the standards should be.

The effect of all this on the operators was, of course, anything but good. They, too, realized that the standards were elastic and quite naturally, in the interests of high earnings, attempted to produce a quality of work which they felt would just pass inspection. As is usual in such cases, they worked more accurately than necessary when studies were being made and decreased the quality immediately the rate was set. Because the methods engineers, too, were using judgment in setting rates, the rates appeared low for the quality that was produced while the study was being made. As a result, disputes were frequent. The methods engineers could not openly say that the inspectors would ease up on their requirements or tell the operators that an inferior quality would pass later on, and yet they knew this would be the case. The operators knew it too; but that, of course, did not prevent them from arguing in favor of higher rates.

Because the operators used their own judgment as to what constituted acceptable quality, jobs were produced more or less frequently which were below the limits that the inspectors felt should be maintained. Therefore, they would reject work of this sort. This immediately caused a protest, again because standards were elastic. The operators were not paid for rejected work, and so naturally they tried to argue the job through. The value of the scrapped work was charged to the foreman's defective work account; and since he was subject to criticism when his defective charges were high, he, too, disputed the inspector's decision. Frequently, he would go to his superintendent with a plausible account of why the inspectors were unduly severe.

The superintendent himself, realizing the elasticity of the requirements, might call upon the engineering department to check the job and to see whether or not the parts could be used. The engineers, anxious in the company's interest to salvage what they could, would sometimes pass work that the inspectors rejected. This, of course, only served to encourage the operators and foremen to dispute still more vigorously each rejected job and to cause the inspectors to lose confidence in their own judgment.

As a result of this condition, the organization could not function properly or effectively. Because of the constant element of doubt, each man used his own judgment. This judgment, on the part of the supervisors at least, was based upon what the individual considered to be for the company's best interest, to be sure, but each one was striving for a different objective. The inspectors wanted the best quality they could get, the methods engineers wanted the lowest cost commensurate with acceptable quality, and the foreman wanted a satisfied working force with a minimum of rejected work. Because they had no common base from which to work, however, disputes were endless, and there was a decided lack of harmony among the various branches of the organization.

The conditions described above occur whenever inspection requirements are not accurately established and rigidly adhered to. Unfortunately, they are encountered all too frequently in industry. In all probability, they develop from small beginnings. No plant deliberately sets up elastic inspection requirements. No matter how rigidly they are set up, however, if exceptions to the requirements are made from time to time without correcting the drawings or other manufacturing instructions, a looseness will creep in that will develop more or less rapidly into the undesirable condition just described.

Therefore, whenever an analyst, be he a methods engineer or other shop executive, encounters a situation of this kind, he will save himself a great deal of future trouble if he will abandon his analysis work temporarily and endeavor to convince his management of the importance of fixed inspection standards. The justness of a policy which says that a part must either meet fixed standards or be rejected and which insists that if a substandard job is passed the standards must be changed is so obvious and the benefits accruing are so apparent that it should not

be difficult to get the management to agree to its establishment. At first, there may be a tendency to wish to deviate from the policy occasionally in order to salvage a lot of costly material, but this is a shortsighted procedure that will only pave the way for a return to previous conditions.

Questions.—In the remaining discussion of the analysis of inspection requirements, it will be assumed that requirements are definite and fixed. The following questions should be raised and, as always, answered only after careful consideration:

1. What are the inspection requirements of this operation?
2. What are the requirements of the preceding operation?
3. What are the requirements of the following operation?
4. Will changing the requirements of a previous operation make this operation easier to perform?
5. Will changing the requirement of this operation make a subsequent operation easier to perform?
6. Are tolerance, allowance, finish, and other requirements necessary?
7. Are they suitable for the purpose the part has to play in the finished product?
8. Can the requirements be raised to improve quality without increasing cost?
9. Will lowering the requirements materially reduce costs?
10. Can the quality of the finished product be improved in any way even beyond present requirements?

Relation of Methods Study to Quality.—Methods studies are made primarily for the purpose of eliminating waste and reducing costs. In so doing, however, it goes without saying that nothing should be done to impair the quality of the finished product or its salability. Because the methods engineer is interested in enhancing the competitive position of his company's products, he quite naturally must take a keen interest in the factor of quality. Products of superior quality outsell products of inferior quality, other things being equal; hence, an improvement in quality is always desirable, provided, of course, that it is necessary and useful quality. Any improvement that betters the functioning, appearance, or salability of the product should be constantly sought. Unnecessary quality, however, refine-

ments that add to the cost of the product without in any way improving it, should be eliminated.

Sometimes it is difficult to decide whether a certain requirement is an unnecessary refinement or a desirable improver of quality. Such questions can be answered only after a thorough discussion of all of the factors involved. In general, however, because of the competitive condition existing in industry, any suggested improvement in quality that can be made without taking the product out of its price class should be adopted.

The methods engineer is in a good position to make suggestions that will improve quality. Because he studies a product in detail and considers thoroughly every factor connected with it, he is quite likely to discover ways of making the product better. In addition, because he eventually sets up working methods that are easy, efficient methods, and because he trains all operators to follow those methods, a higher and more uniform quality of workmanship results than where each operator is left to develop methods for himself. As a result, therefore, methods study tends to raise the quality of the finished product.

Results of Analyzing Inspection Requirements.—For machine work, the limits of accuracy within which the part must be machined are customarily specified on the drawing of the part. These allowances are worked out by the design engineers and are based upon the function the part is to play in the finished product and the relation of the dimensions of the part to the dimensions of the other parts with which it is used. Theoretically, the allowances established by the design engineers should be correct; but because the human element enters in here as elsewhere, they should be carefully checked by the analyst.

Close tolerances raise the cost of a machining operation by making it necessary for the operator to work accurately, checking his work frequently. More cuts are necessary if dimensions must be held accurately, and perhaps even additional operations on other machines. There is a tendency for designers to specify increasingly close tolerances, a tendency that many shopmen deplore. However, the performance requirements of many products are becoming daily more exacting, and as a result accuracy requirements are likely to become increasingly severe. Machine shops, therefore, must face this problem and learn how to work more and more accurately. That this objective

can be attained is evidenced by the remarkable advances being made almost daily in the automotive and aviation industries.

When tolerances are carefully reviewed, some may be found that appear to be unnecessarily close for the function of the part in the finished apparatus. Such cases should be presented to the engineers with a statement of the amount that may be saved by allowing greater leeway. If the tolerance really is too

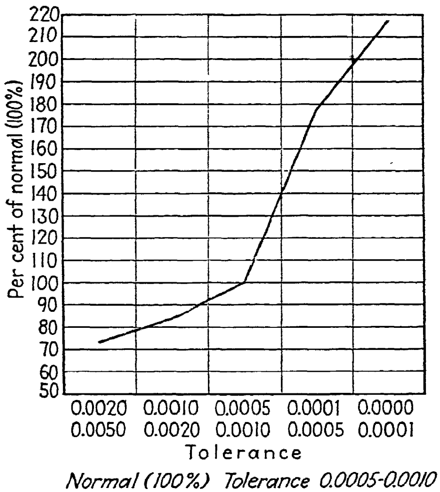


Fig. 50.—Cost increase in per cent for motor-shaft grinding as tolerance decreases.

close and a worth-while saving will be made by increasing it, the change will in all probability be made.

It will aid materially in getting such changes made if charts similar to the one shown by Fig. 50 are available for different classes of operations. Such charts serve to emphasize clearly how much costs are increased as tolerances are decreased. They can also be of value to design engineers for reference purposes.

Occasionally, tolerances are not close enough. Sometimes, by tightening the requirements on a machining operation, the assembly is made easier, and the amount spent on the extra machine work is offset or more than offset by the saving made on the assembly floor. In standardized manufacture, fitting during assembly has been practically eliminated. Parts are machined so that they go together without filing, bending, or

adjusting. The same condition is desirable in small-quantity production where much fitting is commonly done, and it can often be approached by tightening the accuracy requirements on the principal parts.

When a product is made to sell for a price, as, for example, a certain grade of shoe, the matter of allowed quality becomes extremely important. It is possible to add operations almost indefinitely that will improve quality, but the added cost will take the finished shoe out of its price range. Hence, it becomes necessary to determine what can be done for the amount of money available. In a situation of this kind, labor effectiveness is of paramount importance. The more effectively operations are performed, the more operations can be done. The more operations, the better the quality, and, hence, the better the competitive position of the shoe.

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CHAPTER XIV

OPERATION ANALYSIS—MATERIAL

Material cost is a very important part of the total cost of any product. Therefore, although the material of which any part is made is usually fixed by the nature of the part and the service conditions that it must withstand and although the material is usually specified by the designer, engineer, stylist, or perhaps sometimes the purchasing agent, the analyst should nevertheless check the material at least briefly. The ever-present human element sometimes leads to the use of a wrong or too costly material, and the methods engineer, because of his close contact with all kinds of materials during manufacturing processes, may be able to suggest a substitution.

Questions.—The following questions will prove suggestive in connection with an analysis of material:

1. Does the material specified appear suitable for the purpose for which it is to be used?
2. Could a less expensive material be substituted that would function as well?
3. Could a lighter gage material be used?
4. Is the material furnished in suitable condition for use?
5. Could the supplier perform additional work upon the material that would make it better suited for its use?
6. Is the size of the material the most economical?
7. If bar stock or tubing, is the material straight?
8. If a casting or forging, is the excess stock sufficient for machining purposes but not excessive?
9. Can the machinability of the material be improved by heat-treatment or in other ways?
10. Do castings have hard spots or burned-in core sand that should be eliminated?
11. Are castings properly cleaned and have all fins, gate ends, and riser bases been removed?
12. Is material sufficiently clean and free from rust?

13. If coated with a preserving compound, how does this compound affect dies?
14. Is material ordered in amounts and sizes that permit its utilization with a minimum amount of waste, scrap, or short ends?
15. Is material uniform and reasonably free from flaws and defects?
16. Is material utilized to the best advantage during processing?
17. Where yield from a given amount of material depends upon ability of the operator, is any record of yield kept?
18. Is miscellaneous material used for assembly, such as nails, screws, wire, solder, rivets, paste, and washers, suitable?
19. Are the indirect or supply materials such as cutting oil, molding sand, or lubricants best suited to the job?
20. Are materials used in connection with the process, such as gas, fuel oil, coal, coke, compressed air, water, electricity, acids, and paints, suitable, and is their use controlled and economical?

Special materials will evoke special questions, but the list here given will indicate the kind of questions that should be asked and will stimulate suggestions for improvement on many kinds of the more common materials.

Suitability of Material.—In by far the majority of cases, the material best suited for the job is specified in drawings or manufacturing information. Designers are familiar with the characteristics of materials and usually know the least expensive form in which they may be obtained. At the same time, they are not infallible, and shopmen are often able to offer valuable suggestions. For a standardized product, the most suitable material is usually found very soon after the development has begun; but on special work built more or less to customer's order, the checking of material is an almost daily task.

The use to which the part being analyzed is being put should first be considered. Then the material specified should be examined for suitability. Next, the possibilities of using a less expensive material should be considered. Cast iron can sometimes be substituted for brass, or a plastic material for metal.

New materials are constantly being developed. New alloys of metals and new plastic materials are being made available almost

daily. All these materials have different properties, and a certain characteristic may make the use of a certain special material desirable. Some materials are strong, some elastic, some tough, some durable. Others have peculiar magnetic properties, or are acid resistant, or are light in proportion to their strength.

With so many materials available, it is possible to specify a different material for almost every part made; and theoretically, at least, advantages would be gained by so doing. The use of too many materials, however, greatly complicates manufacturing problems. Materials bought in small quantities are usually higher priced. They must be kept separated and identified, which in itself is no small task, since many materials with different properties look exactly alike to the eye. Materials have different degrees of machinability, and every time a new material is introduced an investigation must be made to see what feeds and speeds should be used. Operators working with a variety of materials cannot be so familiar with the best methods for machining them as when fewer are used and hence are not able to produce so much. The difficulty of keeping scrap, chips, cuttings, and short ends separated and identified increases in proportion to the number of materials used.

From a shop standpoint, therefore, a limited number of materials is desirable, and this should be continually pointed out to those who are charged with the responsibility for specifying materials. Otherwise, new materials will be specified frequently, and the shop will soon find itself with a major problem on its hands.

Where many materials are used, every effort must be made to see that the correct material is specified and used. Errors are almost certain to be made and if not detected may lead to serious consequences. In a certain plant where a large number of materials was used, in making up a bill of material, the engineer intended to have a part made of cast steel. In writing down the number, however, he wrote the number used to designate cast iron. It was the sort of mistake that everyone makes from time to time. One thing is meant and another is written in a moment of distracted attention or absent-mindedness.

This particular error was not detected by anyone, and the part was made of cast iron. Unfortunately, it was used on an

apparatus that rotated at high speed. When subjected to stress on test, it failed and killed two men. This was an exceptional case, to be sure, but it shows that errors, usually not serious, occur and that therefore a careful check of material should be made.

If the properties of a given material are satisfactory, it can sometimes be furnished in different forms. For example, a certain part may be made from a casting or a forging, or it may be machined from bar stock. The methods engineer is in a good position to know which form is the least expensive in any given case and hence can offer cost-reducing suggestions.

The substitution of one type of material for another offers many possibilities. Die castings may prove superior to stampings on a certain job, or a stamping will be cheaper than a casting. On one job, wood may be better than metal, whereas on another the reverse may be true. Standard sections of steel as, for example, angles, I-beams, or H-beams cut to length on a cold saw may replace a more expensively formed part.

One of the outstanding cases of substitution that has occurred in recent years was originally initiated by a methods engineer. In investigating the cost of certain large metal rotors, he suggested that instead of being made out of cast steel, as was then the practice, they should be made up of a bar-stock center, bar-stock spokes, and a forged rim all welded together. This was tried and proved so successful and so economical that other applications for welding were sought. In the course of a comparatively brief time, welded or fabricated parts almost entirely replaced steel castings in this particular plant, and an impetus was given to the use of welded parts throughout industry.

Reference has been made mostly to the metal-working field thus far, but the same remarks apply to other types of industry. The textile mills have a wide variety of materials to work with, and new synthetic materials are constantly being developed.

In the manufacture of shoes, various materials are available for soles, and the uppers are made from all manner of things. In this case, the methods engineer often has little or nothing to do with the material specified, but he can furnish cost information in connection with the yields obtained from various classes of material and from time to time as the occasion arises can keep the matter of material cost in the foreground by questions or suggestions.

Size and Condition of Material.—When the suitability of a given material and the form in which it is to be furnished have been fixed upon, the next point to consider is the size and the condition in which the material is furnished. Castings, for example, are furnished with excess metal which is removed during machining. This excess should be sufficient so that the casting will machine properly and so that all machined surfaces will clean up, but it should not be any greater than necessary. Extra metal adds to the weight and hence to the cost of the casting, and additional labor is required to remove it.

Castings sometimes come from the foundry in varying degrees of hardness. This causes machining difficulties, and when a lot of hard castings is received, the operators usually request a higher time allowance from the methods engineer to compensate them for the time lost on extra grinding of tools and taking extra cuts. This request must be granted if extra time is actually required, but an investigation into the causes of the hard castings should be made so that the condition will not be repeated.

Castings when taken from the sand have considerable excess metal in the form of fins, gates, sprues, and risers. This is supposed to be removed by the cleaners in the foundry, but it is not always done carefully. In a plant making a nickel-plated product, the methods engineer was requested to authorize and establish an incentive rate on the operation "prepare casting for plating." Investigation showed that this preparation consisted of grinding rough spots on the castings. The methods engineer, having had foundry experience, realized that this roughness should have been removed in the foundry. Further, he realized that it was not removed because the roughness was excessive owing to a pattern defect. He had the pattern corrected and showed the foundry exactly what was required in the way of finishing. He arranged with the inspector of incoming material to return to the foundry any improperly finished castings. As a result, the necessity for the "prepare casting for plating" operation was eliminated.

Lighter gage material can often be substituted for heavier. On parts turned from bar stock, the maximum diameter fixes the size of the bar to be used. In the case of the part illustrated by Fig. 51, the greater part of the original bar-stock material is scrap. If a design change can be made so that the diameter A is reduced, considerable material will be saved.

Sometimes, material can be ordered very close to the desired size. In other cases, it is cheaper to order a standard size of material, for the cost of the excess material will be less than the extra cost of having material furnished to the exact size. Lumber, for example, comes in certain standard sizes. It is better to order these sizes and then cut them to finished dimensions than to order the material to a special size. The supplier will merely cut the special size from a standard size and, since the excess material is scrap, will charge for it anyway. In addition, because he is not set up to furnish special sizes, it will

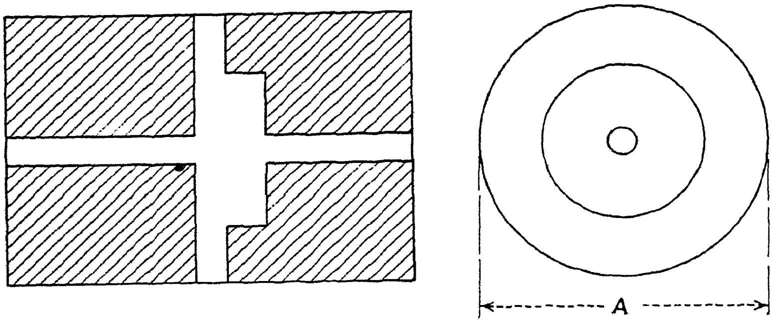


FIG. 51.—Design changes may permit more effective utilization of bar-stock material.

require a special procedure to put an order for a special size through his mill, and he will charge accordingly.

In the case of sheet metal, certain suppliers charge a fixed amount per standard sheet cut to any size desired. In this case, the exact size wanted can be ordered. The excess material is paid for in any event; but by having the sheets cut to size at the mill, the cost of shipping the excess material and of handling and returning it to the steel mill is saved. The scrap value is realized through a credit granted at the mill.

Occasionally, slight design changes can be made to a purchased material that will not affect its cost but will make it easier to use. In other cases, economies may be effected by requesting the supplier to furnish material lined up in an orderly manner. Suppliers have to pack materials in any event and, if they are shown how a certain kind of packing will help the customer, are usually glad to do it as he desires.

Effective Use of Material.—Because many materials are expensive, they should be used with a minimum amount of waste. Waste can sometimes be eliminated by proper design. Bar stock, for example, comes in certain standard lengths. It may be possible to design a given part so that the length of the part plus the amount of metal lost when cutting off will divide evenly

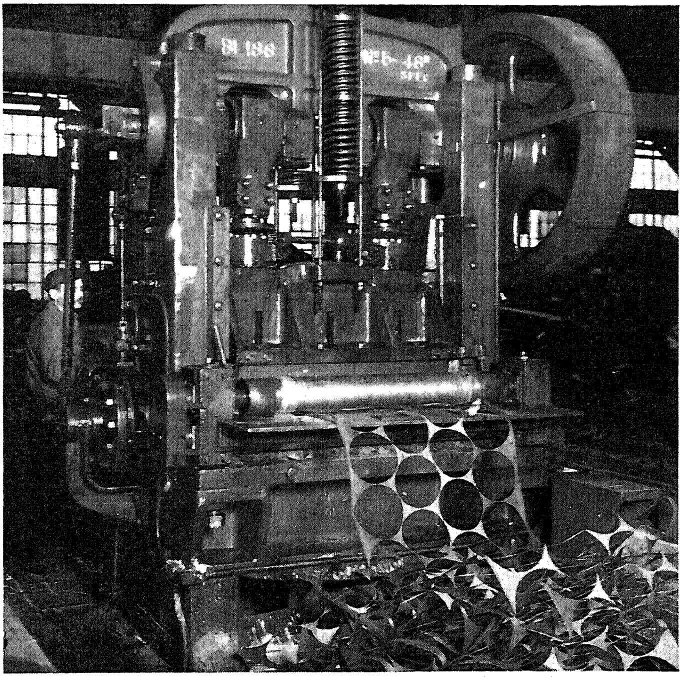


FIG. 51*A*.—Press making blanks for electric-motor laminations.

into a standard bar length, which of course means no short end left over.

In press work, a fairly large section of sheet metal may be punched out, as when a window opening is blanked out of an all-steel car body. This material represents scrap at the blanking operation, but it may be utilized for making smaller stampings and will be just as satisfactory as virgin stock.

Another good example of the effective utilization of material occurs in the making of electric-motor stator and rotor lamina-

tions. Round blanks are first blanked out as shown by Fig. 51*A*. The blanks in adjacent rows are staggered so that the minimum amount of waste occurs on this operation.

The blank *A*, Fig. 51*B*, is then put through another press operation where the stator lamination *B* results. A number of these laminations are built up to form the stator core shown at *C*. The scrap resulting from the stator punching operation is shown at *D*. This is trimmed in another press operation to give the blank *E*.

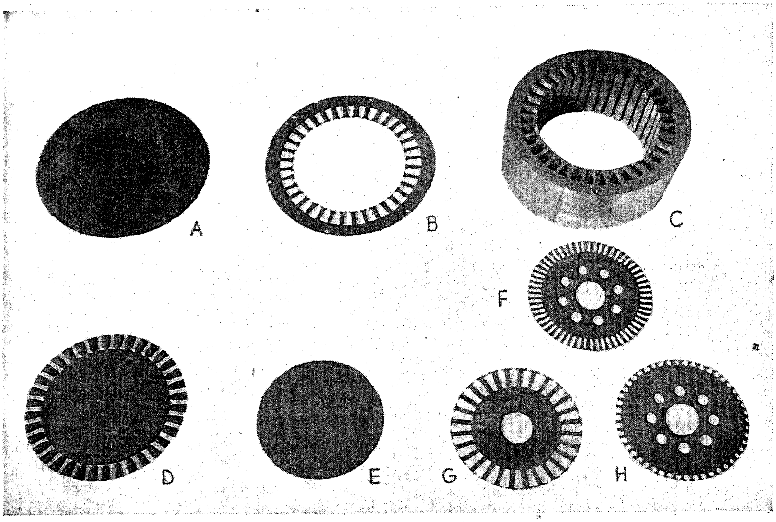


FIG. 51*B*.—Scrap center, *D*, from stator lamination, *B*, furnishes blank, *E*, for three styles of rotor laminations, *F*, *G*, or *H*.

The blank in turn may then be made into any of the three styles of rotor lamination shown at *F*, *G*, and *H*.

In some cases, the proper utilization of material is a responsibility of the operator. If the material is uniform as in the case of cloth or patent leather, the most effective way of cutting the material can be predetermined, and the operator can be instructed. If, however, the material varies, as in the case of kidskins used for the uppers of shoes, the effective use of the material depends upon the ability and judgment of the operator. Thin spots or holes must be cut around, the heavier parts must be used for the parts of the shoe subjected to the greatest strain, and, if the color varies, parts that are to be sewed together must be cut from parts of the skin that match.

To perform a job of this kind properly, considerable individual skill is required. Careful instructions can be given and guides to proper cutting in the form of photographs of properly cut skins such as Fig. 52 can be furnished; but because of the variables encountered, yield or effective utilization is dependent upon the ability of the operator. In cases of this kind, where incentives are used, payment should be based upon yield as well as quantity cut.

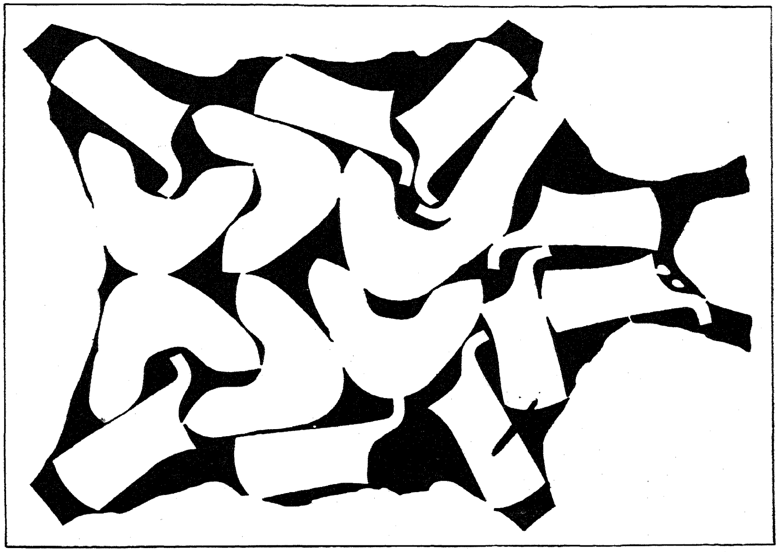


FIG. 52.—Photograph of properly cut skin furnished cutting room operators in shoe factory with a guide to effective material utilization.

Salvage Materials.—Sometimes, worth-while savings can be effected by finding a use for material that has heretofore been scrapped. Many large organizations have shown a recognition of this fact by establishing salvage departments whose duty it is to see that the maximum use is obtained from all materials before they are scrapped and that scrap material is handled in such a way that the highest price is obtained for it.

When a salvage department was first organized in a large automobile-body plant, it was found that all wastepaper was being baled together and sold for a comparatively low price. Investigation showed that if various kinds of wastepaper were kept

separate a higher price could be realized. This was particularly true of cartons, and since the plant received a large amount of supply material packed in this type of container, a worth-while saving was made by handling cartons separately.

The company did quite a volume of business in unassembled or "knocked-down" bodies. It gathered together all the material necessary for bodies and shipped it in sets to branch assembly plants. Part of this material the company manufactured itself, and part was obtained from other suppliers. Much of the material obtained from outside sources came packed in cartons which accounted for the large volume of used cartons mentioned above.

When sets of parts for a body or a group of bodies were prepared for shipment, the smaller parts were packed in cartons. For some time, it was the practice to purchase new cartons for this purpose. The salvage department, however, in looking for economies, developed a workable procedure for re-using the cartons in which material was received for packing the sets of small body parts, and hence was able to eliminate the purchase of new cartons.

Many of the purchased parts were used in fixed quantities per body ranging from 1 or 2 to 64 or more. The parts were received in dozen, hundred, or gross lots and had to be counted out and repacked. The suggestion was made that it might be possible to get the suppliers to pack the parts in the correct quantities for one body so that this unpacking, counting, and repacking could be eliminated. Investigation showed that in many cases the suppliers were glad to do this at no additional cost, and a still further saving was realized. This example shows how profitable a consideration of salvaging materials may be and how one improvement leads on to another.

Supply Materials.—Many processes require materials that are necessary to the process although they are not part of the product itself. Molding sand, gas used for heating furnaces, compressed air, and cutting compounds are all examples of supply materials. Some of these materials vary in suitability to a given job, and all are costly and should be used properly.

An investigation of supply materials is not usually made during a single operation analysis, for the investigation would consume too much time. They should be considered, however, and if

there is a question concerning their suitability or use, a more thorough study can be made when time permits. Experiments may be made with different kinds of supply material which should lead to the selection of the kind best suited to the particular conditions. If the consumption of a material is in question, meters or other measuring devices may be employed to check consumption against quantity of product turned out.

A study of this sort was made in a foundry that operated on a 5½-day basis. It was shown definitely that the consumption of gas, electricity, oil, and air was far greater per pound of castings produced on the ½ day worked than for the 5 full days. Furnaces and core ovens had to be preheated each morning, and the fuel used for this purpose was the same, regardless of the length of time worked after the preheating period. The investigation showed that ½-day operation was uneconomical, and the foundry went on a 5-day week schedule long before the 5-day week was generally adopted by industry.

Another class of supply materials consists of such parts as nuts, bolts, washers, tacks, solder, and so on; and here, too, opportunities for savings exist. For example, a piece of upholstery material was attached to a backing board by 65 tacks. Investigation showed that paste would hold the material in place satisfactorily. Thus, not only were 65 tacks per job saved, but the labor of driving them was also eliminated.

Conclusion.—When the number of different possibilities for improving the material used for a given part are considered, it is seen that the analyst cannot afford to accept the suitability of any material without investigation. Theoretically, perhaps the designer should have considered all or almost all the points discussed, but the methods engineer in reconsidering them from his viewpoint discovers enough opportunities for improvement to justify this step of his analysis procedure several times over.

CHAPTER XV

OPERATION ANALYSIS—MATERIAL HANDLING

The subject of material handling is so important that whole books can be and are devoted to its discussion. The handling of material costs money, and therefore it should be eliminated or reduced as much as possible.

Strictly speaking, about 90 per cent of all industrial activity is material handling, and the balance is actual processing. The material must be transported to the work station, it must be handled by the operator before and after processing, and finally it must be taken away again. On a punch-press operation, for example, the processing time is the time required for the press to make a single stroke, about $\frac{1}{100}$ minute on the average. All the rest of the labor expended on the part is material handling.

From a broad, general standpoint, the part that is least handled by human labor is the best handled. Material handling adds nothing to the value of the part, although it does increase its cost. Therefore, a determined attempt should be made to reduce material handling to an absolute minimum. When sufficient study is made, the extent to which this can be done is often remarkable.

The material-handling problem resolves itself into two natural subdivisions, the handling of material to and from the work station and handling at the work station. These will be discussed briefly and separately.

Material Handling to and from Work Station.—There are a number of different ways of transporting material to and from work stations, and the one which is the most effective will depend upon such individual conditions as the size of the material to be moved, the amount, the frequency of movement, and the distance transported.

The oldest, and probably even yet the most commonly employed method is movement through human agency. A move man or an operator carries or trucks material from place to place.

In certain instances, this is a proper and efficient method. For example, if a given material is so light and so small that a supply sufficient for 2 hours work can be carried in a container the size of an ordinary bread pan, a mechanical means of transportation would be uneconomical. The handling time during the process of manufacture between operations may be as little as 1 per cent of the total processing time, because of the large number of pieces that may be carried at one time. This could undoubtedly be

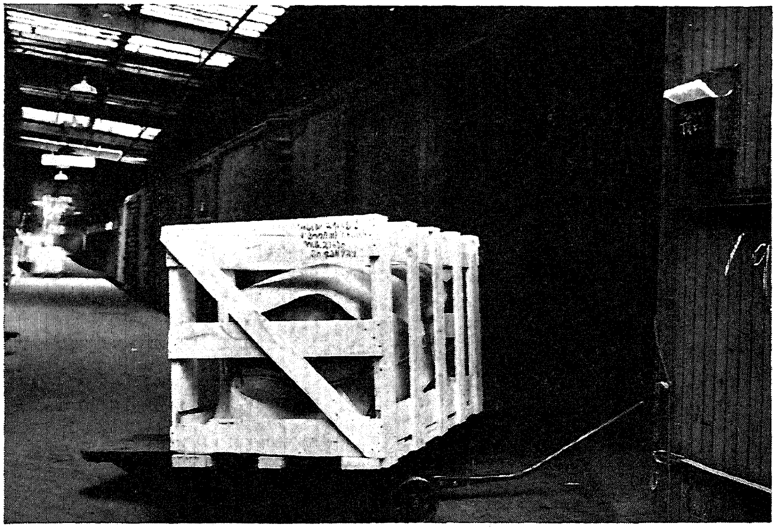


FIG. 53.—Hand truck used to transport heavy or bulky material.

reduced somewhat by relaying out the work space and arranging the operators so close together that they can pass material from one to the other without getting up. Even this is not particularly desirable, however, for little if any real saving would be made. The operations performed on such parts are usually rapid and comparatively monotonous. Getting up and going for a fresh supply of material every 2 hours or so breaks the monotony and actually acts as a rest period by providing a change of occupation. If the handling operation did not provide this interruption and rest, fatigue would cause the operators to seek it anyway by extra trips to the washroom or drinking fountain. Material handling on small parts that provides an occasional break during

a monotonous operation is desirable, and no attempt should be made to eliminate it.

Hand Trucks.—The larger the parts are, the more effort is required to handle them by hand. Added weight involves added muscular effort, and added volume means more trips to transport a given number of pieces. As weight and volume increase, trucks of some sort become increasingly desirable. Hand trucks of the

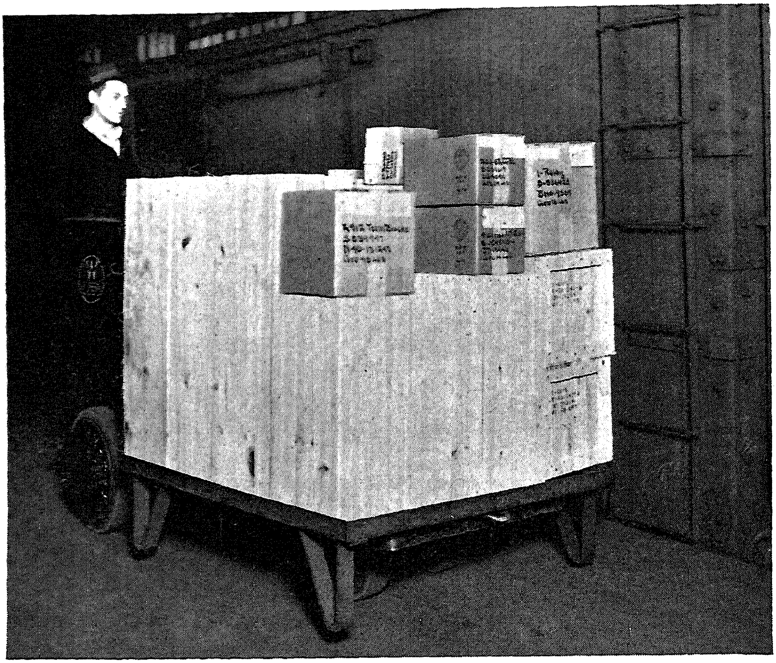


FIG. 54.—Electric truck facilitates the handling of material.

sort illustrated by Fig. 53 are widely used in industry for the transportation of bulky material. Human labor is required to push them from place to place, but they add to the effectiveness of that labor by making it possible to move a large number of parts easily and at one time.

Hand trucks are superior to no trucks at all, but they offer a number of disadvantages. They are bulky, and since they must be pushed through the aisles that are used by anyone who desires to go from one part of the plant to another, with or without

material, they cause interference to easy movement and often serious congestion. Where only one aisle is available, empty trucks commonly flow back against the stream of loaded trucks. In addition, the trucks occupy considerable valuable floor space at the various work stations. The replacing of hand trucks by conveyers will often result in worth-while economies.

Fig. 55.—Special movable rack for handling armature coils through impregnating process.

Electric Trucks.—Electric trucks are used for much the same purpose as hand trucks. They require the services of an operator, but usually more material may be handled per trip, and handled faster. Electric trucks are made in a number of different styles, and special trucks are made for special applications. A common type of electric truck is shown by Fig. 54. Besides being used for material handling, it may be used to haul trucks that would otherwise have to be pushed or pulled by human

labor. For instance, armature coils are placed on a special movable rack for impregnating with insulating compound and baking as shown by Fig. 55. These racks are quite heavy, but they may readily be moved by attaching them to an electric truck.

Tractor-trailer Systems.—When miscellaneous material must be transported to a number of different places located over a large area, electric trucks may be replaced to advantage by a tractor-trailer train such as is illustrated by Fig. 56. This particular train replaced eight electric trucks. Before its installation, the electric trucks were used to transport material, some of them being assigned to specific departments and some operated from a central point. Wherever material had to be moved, the electric trucks were used. The departmental trucks took finished material to other departments and usually returned empty. The other trucks were sent empty to whatever part of the plant they were needed. They did the required moving and then returned to the dispatch station empty. An earnest attempt was made by the dispatcher to route the trucks so that they were loaded as much as possible, but it was a difficult task. In addition, often when a rush call for service was received, all trucks were away, and delays were frequent.

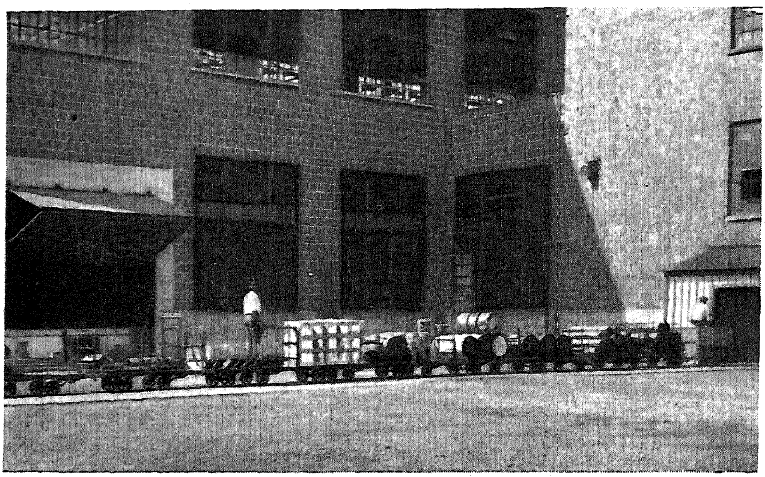


Fig. 56.—Tractor-trailer train used for transporting miscellaneous material to widely separated points.

The installation of the tractor-trailer system reduced labor and greatly improved service throughout the plant. A route was laid out that took the train past every important material station in the plant. A regular schedule was set up, calling for several complete trips per day. The train moved along its route, dropping off trailers at the proper destinations and picking up others bound for different departments. Delays were reduced to a minimum, and each department knew, within a minute or two, the time it would receive incoming material or could ship outgoing material. A few of the old electric trucks were retained at first for emergency service, but the tractor-trailer system functioned so well and gave such rapid service that there was little call for them.

Conveyers.—Conveyers are widely used throughout industry and, where they are properly installed to meet a definite need, will give worth-while economies. Considerable care must be taken to determine if a conveyer will really be an advantage before it is put in, for not all handling problems can be solved by this means. A shop superintendent was once heard to refer contemptuously to an elaborate overhead conveyer system as a "traveling storeroom." As a matter of fact, this is just what it amounted to. Because there was no real need for a conveyer in this department, it was used principally to keep unwanted material off the floor. Material would sometimes slowly circle the department for a week at a time before it was removed from the conveyer. This was wasteful, of course, and was the direct result of an improper installation.

There is a wide variety of kinds and types of conveyers offered by conveyer manufacturers for industrial use. Since conditions in every plant differ, all installations are in a sense special, but most conveyers designed to handle standard materials such as cartons, boxes, or tote pans are made up of standard sections or units. Gravity conveyers are in general cheaper than power-driven conveyers but, of course, require that the opposite ends of the conveyer be at different levels.

A conveyer does not have to be expensive or even purchased to be effective. Often a homemade arrangement of wooden boards will be as efficient as any conveyer that can be installed. On punch-press work, for example, where a product is made in several operations of approximately equal length, if the punch

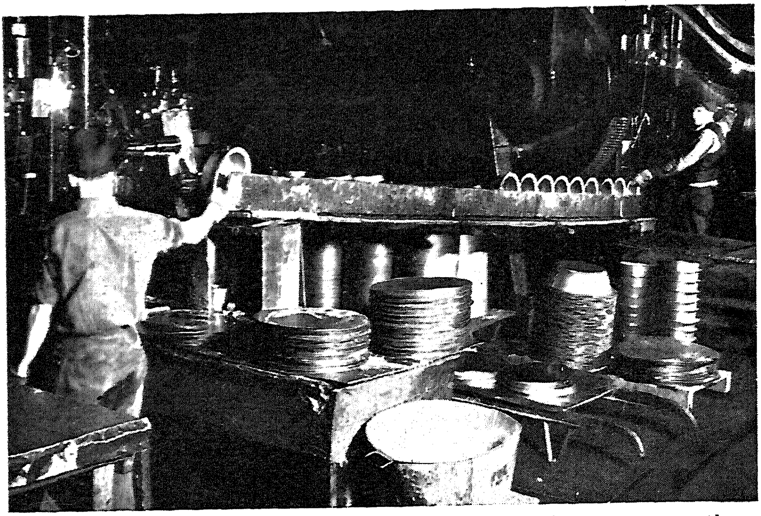


FIG. 57.—Wooden chute used to convey material between draw-press operations.

FIG. 58.—Booster-belt conveyer for raising material level on long gravity conveyer system.

presses are set side by side, wooden chutes such as those shown in Fig. 57 make excellent conveyers. At a given work station, the operator lays aside his finished part in the raised end of a chute. The part rolls or slides to the next operator and arrives in a position convenient for grasping.

Roller conveyers take advantage of the force of gravity to bring about material movement. The rollers run freely on ball bearings; hence, a comparatively slight drop per foot of travel is

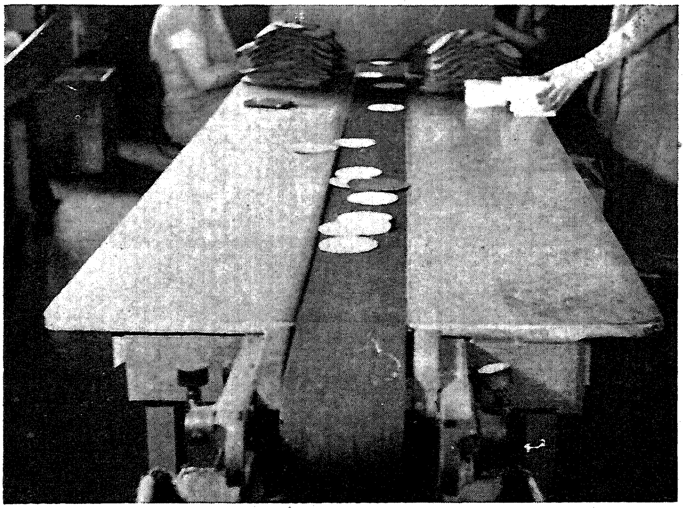


FIG. 59.—Typical belt conveyer for carrying material to and from operators.

necessary. If long distances must be covered, an occasional belt conveyer may be used to boost the material from the low end of one roller conveyer to the high end of the next as shown by Fig. 58.

Other commonly used conveyers are the belt conveyer, Fig. 59, the spiral conveyer which may be either a roller conveyer or a sheet-metal spiral with a steeper pitch, and the overhead chain conveyer, Fig. 60. Many other types are also available, and special conveyers for almost any sort of specific material-handling problem can be obtained. Space is not available for a complete discussion of conveyer systems, but information and advice can be obtained from the leading conveyer manufacturers whenever an installation is contemplated. The main point to be decided

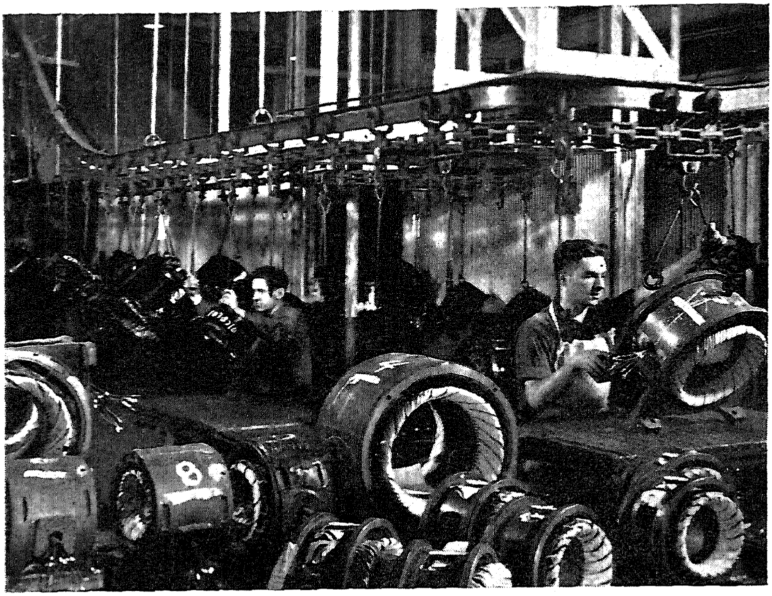


FIG. 60.—Overhead chain conveyer.

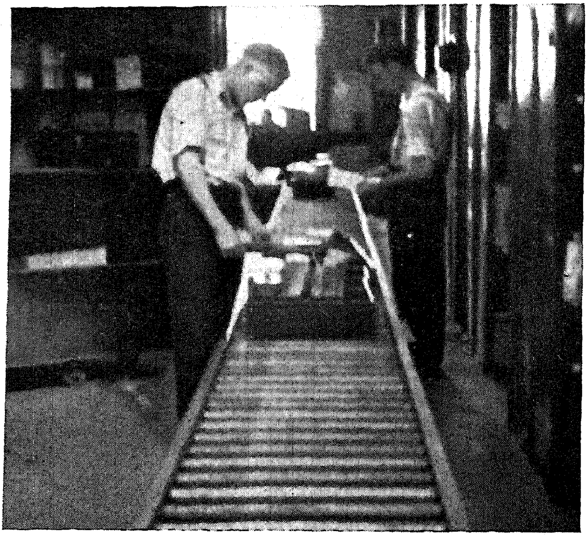


FIG. 61.—Live-roller conveyer for handling miscellaneous material from storeroom to shipping department.

upon first is the necessity for the conveyer. If a conveyer is desirable, a suitable type can always be found.

Conveyers for Miscellaneous Work.—It is commonly felt that conveyers are applicable only where a standard product is manufactured in quantities. Under certain conditions, however, they may be used successfully to handle a miscellaneous variety of work. Figure 61 shows a conveyer running through a storeroom for finished material. A number of miscellaneous products are kept in this storeroom. When an order is received, material is taken from the shelves of the storeroom and is placed on the conveyer which takes it to a checker. When the order has been checked, other conveyers take it to various packing stations for packing and shipping. In spite of the variety of product handled and the number of ways in which orders are packed and shipped, a large saving was made by conveyerizing the stores and shipping department.

Another and perhaps even more striking example of the use of conveyers on miscellaneous work occurred in a machine shop doing milling and drilling operations on small quantities of metal parts. Horizontal milling machines, vertical milling machines, and sensitive, radial, and multiple spindle drill presses were used, and there was a total of 51 machines in the department. Because of the small lot sizes, each machine worked on several different jobs each day. The order in which operations were performed was by no means fixed, for some jobs required drilling before milling, others milling before drilling, and others were milled, drilled, and milled again.

The former layout is shown in the upper half of Fig. 62. Material was moved about by laborers. They brought unfinished material to the various work stations and removed finished material. Material was piled about the machines and, besides occupying floor space, was decidedly unsightly. In addition to the material-handling problems, the matter of proper production control presented difficulties. In every shop, there are always certain jobs that are undesirable from the worker's viewpoint. When a number of jobs are available, the operators will choose the most desirable and will put off doing the least desirable as long as possible. Therefore, the production department has to be continually on the alert to prevent jobs being neglected until they become overdue.

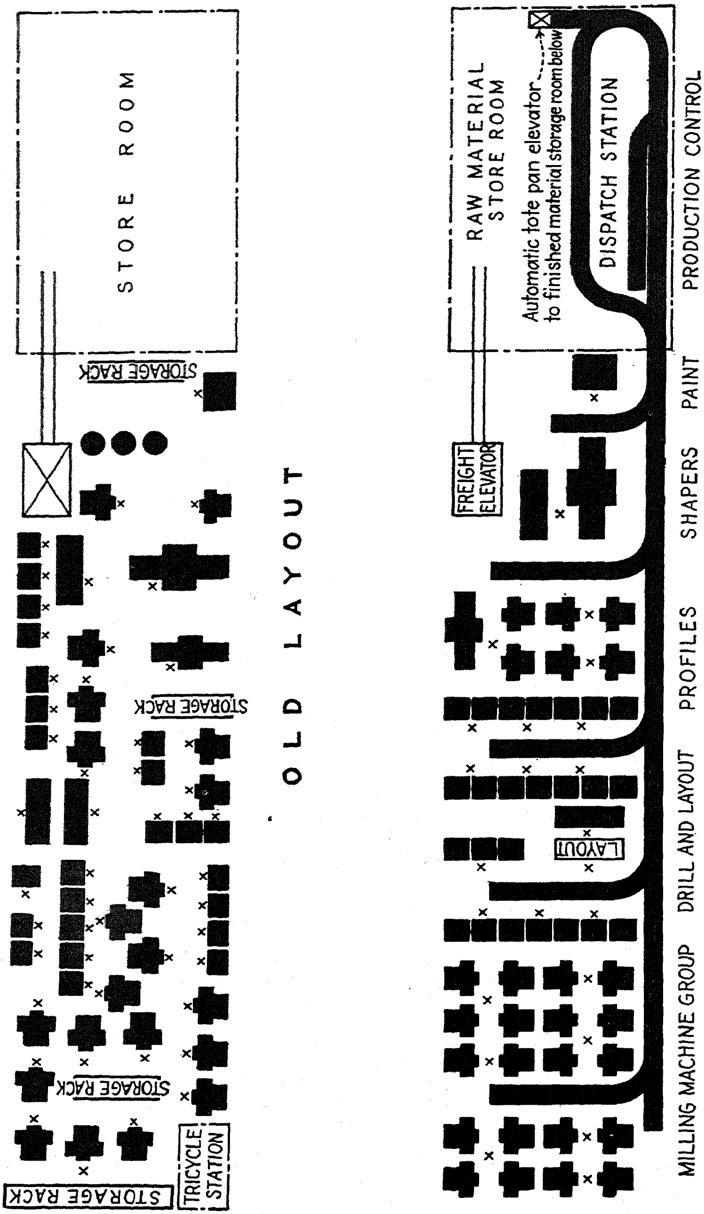


FIG. 62.—Layout of miscellaneous machining department before and after conveyer installation.

A conveyer installation eliminated the move men and overcame production-control difficulties. The layout of the conveyerized department is shown by the lower half of Fig. 62. All material is sent out from the central dispatch station shown on the right of the layout and illustrated by Fig. 63. The dispatcher has a set of records which show when each job is wanted and what the operations are that must be performed. At the proper time, he places material on the outgoing conveyer and by means of a

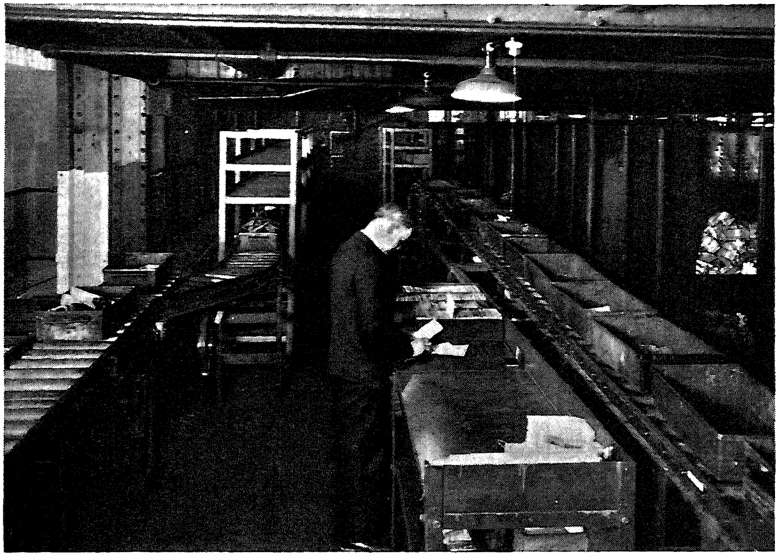


FIG. 63.—Dispatch station for conveyerized miscellaneous machining department.

control apparatus shunts it off on the proper lateral conveyer which takes it to the machines, as shown by Fig. 64. When the operation has been completed, the material is put on a return conveyer located directly below the outgoing conveyer. The job returns to the dispatcher who sends it out to the next operation. In this way, a definite control of the order in which jobs are to be done is obtained. A definite check on the production of each man is available, and certain phases of the clerical routine are simplified.

Material Handling at the Work Station.—When material has been brought to the general neighborhood of the work station,

the handling from that point until the operation is complete is usually done by the operator. When material is brought by truck, move men, or tractor-trailer train, he usually has to walk a varying distance to the material and transport it to working position himself. Conveyers or overhead cranes usually bring the material close to the operator.

When the material is at the work station, it must be picked up and moved to the working position. The work is done, after which the material is set aside. When the job is finished, the

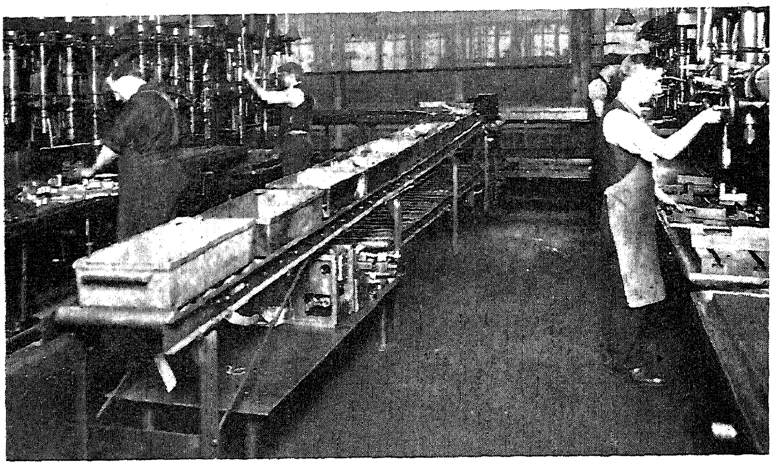


FIG. 64.—Material arriving at workplace on conveyer in miscellaneous machining department.

complete lot of material may be removed from the immediate vicinity of the work station by the operator.

The exact procedure followed will vary considerably with varying conditions and products; but unless the material is brought directly to the operator by conveyer and the work is done on the part while it is still on the conveyer, there will be a certain amount of material handling at the work station. This should be reduced as much as conditions permit. The initial and final moves can sometimes be shortened by rearranging the layout of the department. Material handling at the workplace can be reduced by detailed motion study.

Questions.—The discussion of the material-handling problem given here is of necessity rather brief. No particular mention of

such transportation devices as overhead cranes or elevators has been made, for these are usually provided when necessary and are usually installed and working at the time the operation analysis is begun.

As a matter of fact, the analysis of a single operation seldom leads to the installation of a conveyer system or other expensive handling means unless the operation is highly repetitive. Usually it results in the installation of simple handling devices such as the gravity chutes shown by Fig. 57 or the development of special

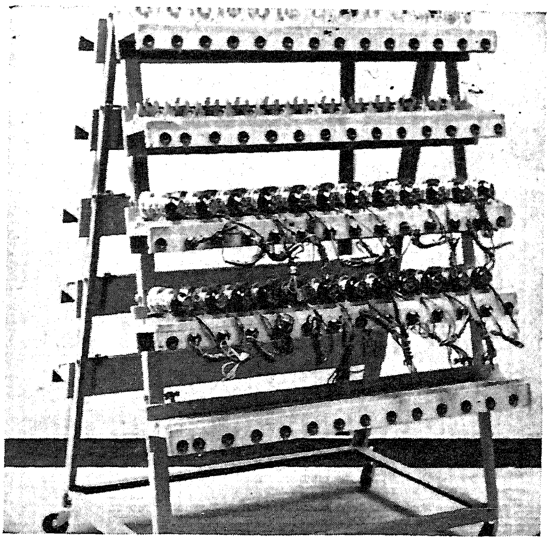


FIG. 65.—Special rack built to facilitate the handling of electric-clock motors.

tote pans or racks as in Fig. 65, which facilitate the handling of the particular job.

At the same time, the desirability of the more elaborate handling devices should be considered. If several analyses indicate that a conveyer system, for example, offers possibilities, then a more general study of material handling may be undertaken. These greater possibilities should be kept in mind during all analyses, therefore; and as a stimulation to all kinds of material-handling improvement, the following questions should be answered by the analyst during the course of his study of the factor of material handling.

1. Is the time consumed in bringing the material to the work station and in removing it large in proportion to the time required to handle it at the work station?
2. If not, should material handling be done by operators to provide rest through change of occupation?
3. Should hand trucks be used?
4. Should electric trucks be used?
5. Should special racks or trays be designed to permit handling the material easily and without damage?
6. Where should incoming and outgoing material be located with respect to the work station?
7. Is a conveyer justified?
8. If so, what type would best be suited to the job?
9. Can the work stations for the successive steps of the process be moved close together and material handling accomplished by means of gravity chutes?
10. Can the operation be done on the conveyer?
11. Can a progressive assembly line be set up?
12. Can material be pushed from operator to operator along the surface of the bench?
13. Can material be dispatched from a central point by conveyer?
14. Can material be brought to a central inspection point by conveyer?
15. Can weighing scales be incorporated to advantage in the conveyer?
16. Is the size of the material container suitable for the amount of material transported?
17. Can container be designed to make material more accessible?
18. Can container be placed at work station without removing material?
19. Can electric or air hoist or other lifting device be used to advantage at work station?
20. If overhead traveling crane is used, is service rendered prompt and adequate?
21. Can a pneumatic tube system be used to convey small parts or orders and paper work?
22. Will signals such as lights or bells notifying move men that material is ready for transportation improve service?

23. Can a tractor-trailer train running on a definite schedule be used?
24. Can an industrial railway running on tracks be used?
25. Can tractor-trailer or industrial railway system be replaced by a conveyer?
26. If helper is needed to handle large parts at work station, can a mechanical handling means be substituted?
27. Can gravity be utilized by starting first operation of a series at higher than floor level?
28. Can scrap or waste material be handled more effectively?
29. Can departmental layout be changed to improve material-handling situation?
30. Should the material-handling problem in general receive more intensive study in the immediate future?

CHAPTER XVI

OPERATION ANALYSIS—SETUP AND TOOL EQUIPMENT

The setup or the workplace layout or both must be studied in detail, for they largely determine the methods and motions that must be used to perform the operation. The order in which tools are set up in a turret lathe, for example, will determine the order in which the various machining operations are performed. The position in which material is placed with respect to the point of use will determine the class and the length of the motions required to secure it.

Before any work can be done, certain preliminary or "make-ready" operations must be performed. These include such elements as getting tools and drawings, getting material and instructions, and setting up the machine or laying out material and tools about the workplace. When the operation itself has been completed, certain clean up or "put-away" elements must be done such as putting away tools and drawings, removing finished material, and cleaning up the workplace or machine.

Questions on "Make-ready" and "Put-away" Elements.—The procedure followed to perform the "make-ready" and "put-away" elements should be questioned closely, particularly on small-quantity work, for these operations are usually fairly long. Many of them carry the operator away from his workplace. This is undesirable for several reasons, and the necessity for trips to other parts of the department should be minimized. The arrangement of the setup or the workplace layout is of primary importance, and the simple rules governing efficient workplace layouts should be clearly understood.

Typical questions which will lead to suggestions for improvement in this connection are as follows:

1. How is the job assigned to the operator?
2. Is the procedure such that the operator is ever without a job to do?

3. How are instructions imparted to the operator?
4. How is material secured?
5. How are drawings and tools secured?
6. How are the times at which the job is started and finished checked?
7. What possibilities for delays occur at drawing room, toolroom, storeroom, or time clerk's office?
8. If operator makes his own setup, would economies be gained by providing special setup men?
9. Could a supply boy get tools, drawings, and material?
10. Is the layout of the operator's locker or tool drawer orderly so that no time is lost searching for tools or equipment?
11. Are the tools that the operator uses in making his setup adequate?
12. Is the machine set up properly?
13. Is the machine adjusted for proper feeds and speeds?
14. Is machine in repair, and are belts tight and not slipping?
15. If vises, jigs, or fixtures are used, are they securely clamped to the machine?
16. Is the order in which the elements of the operation are performed correct?
17. Does the workplace layout conform to the principles that govern effective workplace layouts?
18. Is material properly positioned?
19. Are tools prepositioned?
20. Are the first few pieces produced checked for correctness by anyone other than the operator?
21. What must be done to complete operation and put away all equipment used?
22. Can trip to return tools to toolroom be combined with trip to get tools for next job?
23. How thoroughly should workplace be cleaned?
24. What disposal is made of scrap, short ends, or defective parts?
25. If operation is performed continuously, are preliminary operations of a preparatory nature necessary the first thing in the morning?
26. Are adjustments to equipment on a continuous operation made by the operator?
27. How is material supply replenished?

28. If a number of miscellaneous jobs are done, can similar jobs be grouped to eliminate certain setup elements?
29. How are partial setups handled?
30. Is the operator responsible for protecting workplace overnight by covering it or locking up valuable material?

From this list, it may be seen that an analysis of "make-ready" and "put-away" operations covers a rather wide field. The general plant routine with respect to the way jobs are given out is questioned, as is also the manner in which tools, drawings, and materials are secured. Much of this is standard for every job; and after it has been thoroughly analyzed for one job and improved as much as possible, it need not be considered so carefully again. Too often, however, procedures of this sort have been hurriedly set up or were not set up at all. In the older shops which were in operation before the principles of scientific management were evolved, the routine in effect today may be merely bad habits. Therefore, the subject should receive a thorough analysis at least once, and preferably—so that irregularities will not be permitted to creep in and become standard practice—more often, say at least every 6 months.

Make Ready.—The methods followed in giving out jobs differ widely throughout industry. Where the same operation is worked day after day, the problem is not encountered; but on more miscellaneous work, some procedure for telling an operator what job he is to work upon next must be provided.

In some cases, material to be processed is placed near the work stations of a number of operators. The operators go to the material and themselves select the jobs they wish to do. This procedure involves a minimum amount of supervision and clerical work, but it possesses certain serious disadvantages. As has already been pointed out, some jobs are more desirable from the operator's standpoint than others. They may be easier or lighter or cleaner, or if time allowances are not accurate as is sometimes the case, some jobs may carry looser rates than others, thus permitting higher earnings for a given expenditure of effort. Regardless of the reason, certain jobs are preferable to others; if the operators are allowed to pick their own jobs, friction is likely to develop. Those who have stronger characters or are physically superior are likely to get the best jobs, and the weaker must take what is left. The least desirable jobs will be slighted

altogether as long as there is any other work to do, which causes these jobs to lag and become overdue.

Finally, there is no assurance that the operators will get the jobs for which they are best suited, considering the group as a whole. If the most skilled operator happens to be the strongest, he is likely to select all the easiest jobs, leaving the more difficult jobs to those who are not so well qualified to do them.

Where the group system is used, these difficulties are minimized, but principally because the group leader assumes a function of management and hands out the work to the members of his group. The group knows that sooner or later it will have to handle all jobs sent to it, and so there is less tendency to slight undesirable work. In the interests of good performance as a group, the skilled men will do the more difficult jobs, leaving the easier tasks to the new or less skilled men. In short, the entire situation is changed; when the group system is used, the selection of jobs may be left to the workers themselves.

Another common procedure is to have all jobs handed out by the foreman. The foreman knows the work, and he knows his men. Therefore, he is in a good position to distribute the work so that it will be performed most effectively. The chief difficulty with this arrangement is that the modern foreman is so loaded with duties and responsibilities that he often does not have time to plan his work properly. In moments of rush activity, instead of always having several jobs ahead of each operator, he is likely to assign jobs only when men run out of work. When a man comes to him for a job, he is likely to glance at the available work and assign the first job he sees that he thinks the operator can do. It may not be the one best suited to the operator; perhaps even more important, it may not be the job that is most important from a delivery standpoint.

With regard to this last point, in order to get work through the shop on schedule, the planning or production department must work closely with the foreman. Usually, chasers or expediters call to the attention of the foreman the job that is required next. If there are only a few rush jobs, the foreman may be able to have them completed as desired. In times of peak activity, however, when the shop is overloaded, all jobs become rush jobs. Each expediter has a long list of jobs to be completed at once. Considerable pressure is brought to bear upon the foreman to get

out this job and that, and he is likely to find himself devoting time to detailed production activities that could better be spent on taking steps to relieve the congestion.

In most up-to-date plants, the foreman is regarded as a very important man. He is called into conferences and meetings and often participates in educational programs. He is, therefore, away from his department at intervals and, if he has the responsibility of giving out jobs, must give out enough work to last until he returns. If he is called away suddenly or is unexpectedly detained, operators will run out of work. Then they either lose considerable time and hence money which creates dissatisfaction, or they help themselves to another job. If this latter practice is countenanced in a time of emergency, there is a danger that it will soon develop into a standard practice. If men get their own jobs, the foreman is relieved of a certain amount of work and, if he is otherwise overloaded, may tend to allow operators to select their work with increasing frequency, until all the advantages gained by having the foremen hand out work are lost.

The decisions with respect to the order in which jobs are to be put through the shop are made by the planning or production department. Since they know in what order jobs are wanted, it would, therefore, appear that a representative of this department should cooperate closely with the foreman in giving out the work. The foreman may specify the men who are to work on each job when the orders first reach his department, and a dispatch clerk may give the work to the assigned men in the order of its importance from a delivery standpoint. This arrangement is followed in a number of plants. Figure 66 shows a typical dispatching station under the control of the production department. Time tickets for each operation on each job are made out in a central planning department and are marked with the date the operation should be completed. The dispatcher arranges these time tickets in his dispatch board. Each group of machines within the department is assigned a pocket in the dispatch board, and each pocket has three subdivisions.

The time tickets are received considerably in advance of the material. They are first filed in a subdivision of the proper machine pockets called the "work ahead" division. The number of tickets in the "work ahead" divisions at any time gives a rough idea of the load on the shop. When material for a given

job enters the department, the dispatcher is notified. He then moves the time ticket for the first operation from the "work ahead" division to the "work ready" division. The time tickets in the latter pocket then show the jobs that are actually ready to be worked upon. When an operator completes one job, he goes to the dispatcher's station and turns in the ticket for that job. The dispatcher then gives him another job by taking the

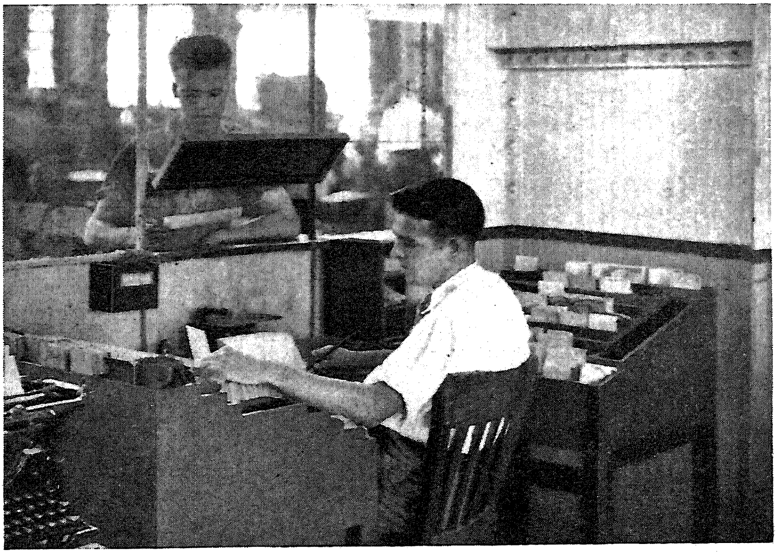


FIG. 66.—Dispatch station for giving out jobs to operators.

time ticket from the "work ready" division and handing it to him. He selects always the ticket marked with the date nearest to the current date and thus gets the work done in the desired order.

The rest of the system need not be described here, for it is desired principally to indicate the manner in which jobs are handed out by a representative of the production department, thus relieving the foreman of this responsibility.

When the operator has received notification in one way or another of the job he is to do, he must next secure drawings, tools, and material. The way in which this is done also varies widely. In some cases, the operator must hunt everything for himself. In others, he goes to a tool- or drawing-room window

and waits while an attendant gets what he requires. In still other cases, everything is brought to him, and he does not have to leave his work station.

The exact procedure that is followed will depend upon existing conditions; but if it is possible to work out an economical system for furnishing the operator with what he needs at his work station, it is desirable to do so. Besides reducing costs, this procedure increases the amount of time the equipment is utilized and thus increases the productive capacity of the plant. Often a low-rated worker can do the errands of the operators and bring tools, drawings, and materials.

Where the group system is used and no supply boy is available, the group leader commonly gets all necessary supplies and tools. By getting the necessary items for several jobs at one time, he is able to effect economies.

If a conveyer system of the type illustrated by Figs. 62 to 64 of the preceding chapter is used, the jobs may be dispatched by the production department in the order wanted, and all material, tools, and drawings can be sent out at the same time on the conveyer. Thus the amount of time spent by the operator in getting ready to make the setup or workplace layout is reduced to a minimum.

The manner in which instructions are furnished with regard to how the job should be done is worthy of careful consideration. In many cases, no instructions at all are given. The operator is supposed to be familiar enough with the work to know how to do it. If not, he may ask the foreman. When no definite instructions are given or when the foreman gives only brief general advice, the method that the operator follows is likely to be one of his own devising which may or may not be effective. The fact that in so many cases different operators follow different methods in doing the same operation may be traced directly to insufficient instruction. To secure effective performance, the best method must first be worked out and then taught.

Some plants employ instructors or demonstrators to perform the teaching function. If these men know the best methods themselves and are good teachers, good results will be secured. Too often, however, the instructor is merely an experienced operator who knows only such methods as he himself used before he was promoted. Even though he was a highly skilled operator,

the chances of his knowing and being able to impart a knowledge of the best methods are small, unless he has received additional training himself in the principles of methods engineering. If he is a machine instructor, he is likely to teach feeds and speeds and the best way to grind tools, mentioning only briefly, if at all, the arrangement of the workplace and the motions that should be used.

Feeds, speeds, and the grinding of tools all are important, of course, but they constitute only part of the method. A lathe operator, for example, was engaged in turning shafts in an engine lathe. Each shaft had to be stamped with a number. The operator would remove a finished shaft from his lathe, turn to a bench, stamp the number, set aside the shaft, pick up another, and return to his machine. The turning required a long cut under power feed. A much better method is as follows: While a cut is being taken, the operator gets the next shaft to be machined; he places it on the machine ways in a convenient position; as soon as the cut is taken, he removes the finished shaft and inserts the other; he starts the cut and then while the machine is running, stamps and lays aside the finished shaft. Thus, the machine runs nearly continuously, and idle time on the part of both the operator and the machine is reduced.

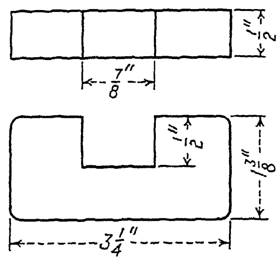
The better procedure described will, no doubt, seem obvious to the reader, and it is, of course, standard practice in many plants. At the same time, the other method is encountered frequently in plants that have given little attention to methods and methods instruction. An experienced lathe operator going from a plant where the first method was common practice to one where the second was in effect would find it difficult to make satisfactory earnings in the second plant. If he were the only one doing this operation and so could not learn the better method by observation, he would be likely to feel that the rate was too tight and would become discouraged. Instruction in some manner with regard not only to feeds and speeds but also with regard to the proper motion sequence would be necessary to correct his difficulty.

Instruction sheets can be used to instruct operators and, under certain conditions, their use is not too costly. A common form of instruction sheet is illustrated by Fig. 67. This instruction sheet and the following one cover the milling-machine operation

INSTRUCTION SHEET

PART - Type X Regulator Clamp	Item 1	Drawing
OPERATION - Mill Slot	Sub. 2	822304

MACHINE TOOL	DEPARTMENT
Horizontal Milling Machines	FORMULA-C No. 1
No. 2 Milwaukee No. 248	SKETCH OF PART
No. 2 Cincinnati No. 863	
No. 3 Le Blond No. 3589	
SPECIAL TOOLS	
7/8" wide x 6" dia.	
special side cutter	
SUPPLY	
Material delivered by	
laborers - man must get	
own tools from crib	
INSPECTION	
Slot dimen. limits ±0.005"	



NO.	ORDER OF OPERATIONS	SPECIAL TOOLS	SIZE OF SLOT	SPEED R.P.M	FEED IN/MIN.
1	Pick up part from table				
2	Place in vise				
3	Tighten vise				
4	Start machine				
5	Move table forward 4"				
6	Engage feed				
7	Mill slot	Side cutter	7/8" x 1/2"	140	6
8	Stop machine				
9	Return table				
10	Release vise				
11	Lay aside part in pan				
12	Brush vise				

DATE	T.S. MAN	FOREMAN	T.S. SUPERVISOR
8/20/38	R. O. B.	W. S.	L. R. G.

FIG. 67.—Instruction sheet for milling operation showing elements of operation.

INSTRUCTION CARD

DATE Aug. 20, 1938

OPERATION Mill Slot

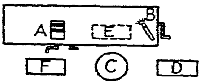
ALLOWED TIME 0.0197 hr.

WORKPLACE LAYOUT

DWG. NO. 822304

DEPT. Small Machining

APPROVED E. A. Boden
METHODS DEPT



A- Standard machine vise
B- Brush
C- Operator's working position
D- Raw material container
E- Supply of material for immediate machining
F- Finished material container

LEFT HAND			RIGHT HAND
		TE	Move to part
		G	Grasp part
		CD	
		TL	Move part to vise
Idle	UD	P	Position part in vise
Grasp part	G	R	Release part
		TE	Move to vise handle
		G	Grasp vice handle
Hold part in position	H	U	Tighten vise
Release part	R	R	Release vise handle
Move to clutch lever	TE		
Grasp clutch lever	G		
Start machine	U	UD	Idle
Release clutch lever	R	TE	Move to table feed handle
		G	Grasp handle
Idle	UD		
	CD		
Move to feed lever	TE		
Grasp feed lever	G	U	Run table forward 4"
Engage feed	U	UD	Idle
Release feed lever	R	R	Release handle
Mill slot	U	U	Mill slot
Grasp clutch lever	G		
Stop machine	U		
Release clutch lever	R		
		UD	Idle and wait for machine to stop
Wait for machine to stop	UD	G	Grasp table feed handle
		U	Return table 5.5"
		R	Release handle
		CD	
		TE	Move to vise handle
Idle	UD	G	Grasp vise handle
Move to part	TE		
Grasp part	G	U	Open vise
	CD	R	Release vice handle
Move part to tote pan	TL	TE	Move to brush
Release part	R	G	Grasp brush
		CD	
		TL	Move to vise
		U	Brush vise
		CD	
		TL	Move brush aside
Idle	UD	R	Release brush

discussed in Chap. X. For the sake of clearness, they describe the procedure for operating one machine only. The form of instruction sheet illustrated by Fig. 67 is good, but it does not go into much detail. Hence, in following it, wrong motions may be used. A more explicit instruction sheet is shown by Fig. 68. This is in reality a form of the operator process chart combined with a description of the workplace layout. It gives complete and detailed instructions and is not difficult to interpret if the general construction of such charts is first explained.

Setup.—The setup of the machine and of any tools, jigs, or fixtures used should be studied in detail. The correctness and the adequacy of the setup should first be considered, followed by a brief review of the methods employed to make it. The correct setup is fixed by the nature of the operation, the nature of the part, the requirements of the job, and the mechanical features of the machine. Sometimes, it is possible to do a job in more than one way, and care should be taken to ascertain that the best way is being used.

Many ingenious ways are tried to extend the time for doing a job during the course of a time study when the operator does not have confidence in the time-study engineer. Belts may be loosened so that they slip under load, improper feeds and speeds may be used, or a carbon steel cutter may be used in place of a higher speed alloy.

An amusing incident occurred when, just before a time study was taken on a milling-machine operation, the operator loosened the bolts slightly that held the vise to the machine table. When the cut was taken, the vise very slowly slid along the surface of the table, and of course, the time for taking the cut was extended. The time-study engineer, as a matter of routine, checked the feed and length of cut and immediately found a discrepancy between his data and what the cutting time should be. It was difficult to detect at first where the trouble lay, but when he stayed on the job and watched, the vise eventually reached a point where it was noticeably out of position. The engineer then merely waited quietly until the vise got near the end of the machine table, smiled with the operator while he reset it properly, and then restudied the job. Mechanical points of this nature are comparatively easy to check, and it is difficult to deceive even a comparatively inexperienced analyst if he is alert.

When the setup is being made, certain tools are usually required. These should be suitable for the purpose. If each operator must make his own setup, he should be provided with the necessary tools. If only one or two wrenches are furnished to a group of 10 operators, for example, the time lost in hunting the wrenches and in waiting for a chance to use them will usually far offset the cost of additional equipment.

If setup men are employed to setup machines ahead of the operators, their setup work is to them fairly repetitive work, because they are performing the same elements day after day. It will therefore be desirable to treat it as such and to furnish the setup men with special-purpose quick-acting tools.

The Workplace Layout.—The improvement of the layout of the workplace of the industrial worker is too often overlooked as a means for effecting operating economies. The layout of the workplace partly determines the method the operator must follow in doing a given task, and it almost wholly determines the motions he must employ. Since certain motions are more fatiguing and consume more time than others, it is quite possible to effect worth-while cost reductions merely by rearranging layouts. The rearrangement usually comes about as the result of detailed motion study. If the underlying principles which govern workplace layouts are understood by the analyst, however, a consideration of the workplace layout will show whether detailed motion study is likely to bring about improvement, and it may also suggest obvious improvements that can be put into effect immediately. For this reason, the principles which affect workplace layouts will be discussed briefly.

Two general concepts underlie workplace layouts. The first has to do with the classes of motions that a human being can make. There are five general classes, as follows:

1. Finger motions.
2. Finger and wrist motions.
3. Finger, wrist, and forearm motions.
4. Finger, wrist, forearm, and upper-arm motions.
5. Finger, wrist, forearm, upper-arm, and body motions.

It is usually stated that motions of the lower classes can be made more quickly and with less expenditure of effort than motions of the higher classes. This, however, is true only when the motions are made under not greater than normal load over

paths of approximately equal length. It might be possible by exerting a prodigious effort to lift a heavy object an inch or so with a finger movement; but the same object could be lifted the same distance in less time, and with far less fatigue, by a finger, wrist, and forearm movement. Similarly, it may be seen that a short fourth-class motion can be made more quickly than a long third-class motion.

In applying the concept of motion classes to actual layouts, the attempt should be made to reduce all motions to the lowest possible class. This, of course, must be interpreted with common sense. In actual practice, with what has been said in the preceding paragraph kept in mind, there is no difficulty in recognizing the lowest *practical* class of motion that can be employed to accomplish any given task.

The lowest class of motion is the finger motion. If a job can be accomplished by using only finger motions, no further improvement can be made. The use of pure finger motions only, however, is seldom practicable. In most layouts, the aim will be to eliminate all body movements, to reduce many fourth-class motions to the third class, and to reduce the length of all motion paths.

The second concept underlying workplace layouts is that of normal and maximum working areas. The area in which the worker performs his operation should be kept at a minimum, as this automatically keeps the class of motions which must be used in the lower classifications.

Figure 69 is a sketch showing how the normal and maximum working areas for the hands in the horizontal plane are usually determined. In drawing the sketch, it is assumed that the worker is comfortably seated at or standing by his bench or table of proper height. His arms hang naturally from the shoulders. Placing his right hand on the near edge of the table approximately opposite his left side, he can sweep his right hand through the arc *AMB*. The area included between this arc and the edge of the table is generally said to represent the normal or most comfortable working area for the right hand.

The points along the arc *AMB* can be reached with a motion of the third class. To reach all other points within the area bounded by the arc, a fourth-class motion must be employed. It requires more time to make a fourth-class motion than it does

to make a third-class motion of the same length. Hence, the arc *AMB* should receive preference when making layouts.

Even when third-class motions can be employed, motions of equal length cannot be made in the same length of time at all points along the arc *AMB*. Motions are made most quickly near point *A* and most slowly at point *B*. When motions must be made much beyond point *M* in the direction of point *B*, fatigue increases materially. The closer the hand approaches *B*, the more unnatural is the position that the arm must assume. In fact, if the elbow rests on the table, the point *B* cannot be reached at all.

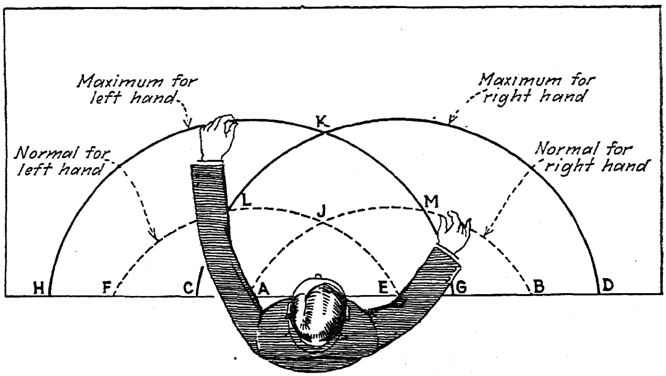


FIG. 69.—Normal and maximum working areas for the hands in the horizontal plane.

The arc which bounds the maximum working area is traced by the fingers when the arm, fully extended, is pivoted about the shoulder. For the right hand, this is arc *CKD* in Fig. 69. The limitations discussed above do not apply to the maximum area. All points can be reached by fourth-class motions, and motions can be made as quickly in one section as in another. In positioning material within this area, the chief concern should be to keep the length of the movements at a minimum. If possible, the section near *BD* should not be used. Besides involving maximum travel, it requires a rather awkward and fatiguing wrist motion to reach material located in bins anywhere except at point *D*, or in other words, when the arm is not fully extended.

The above discussion applies equally to the areas used by the left hand and arm.

In order to confine all motions to the third class, material should be placed along the paths that the hands normally follow, or along the arcs *FLE* and *AMB* of Fig. 69. The only point at which the hands can work together without involving the use of shoulder motions to change the position of the arms is the point *J*. In reality, this is not a point but a small area, which is determined by the wrist and finger motions that can be used without moving the arms.

In the vertical plane, the arc described by the fingers when a third-class movement is made is the arc *AB* of Fig. 70, and the arc *CD* is the maximum arc made employing a fourth-class movement. These arcs determine the efficient placement of materials in the vertical plane.

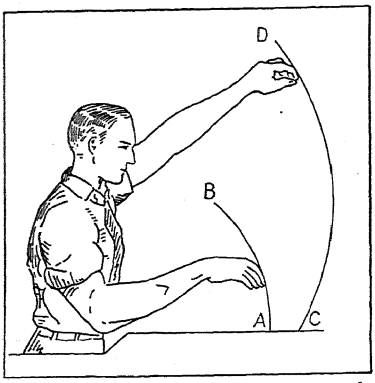


FIG. 70.—Normal and maximum working areas for the hands in the vertical plane.

When positioning tools that are suspended above the work area, care should be taken to locate them within the sphere which would be generated if the arc *CD*, Fig. 70, were to be rotated about the body of the operator as an axis. If no other equipment or material interferes, the tools should be located on the sphere which would be generated by similarly rotating the arc *AB*; but in any case, they should be located so that they can be reached without the necessity of employing body movements.

The principles of efficient work areas should be applied to all lines of work, for they are universal. It is customary to think of them in connection with bench operations; but they can and should be applied to the arrangement of tools and materials around machines or on work such as molding, forging, and the like, and to the arrangement of levers, handwheels, and so on, when designing machine-tool equipment. When the imaginary boundary lines that limit the normal and maximum working areas in all planes are clearly visualized, it is quite easy to detect inefficient arrangements of workplaces and to know exactly what steps must be taken to bring about improvement.

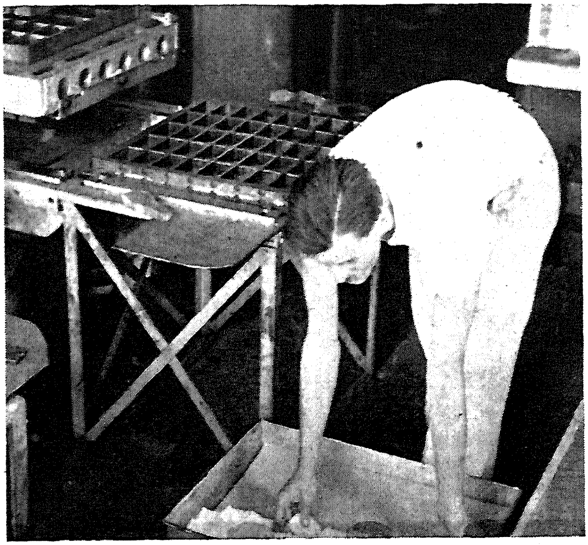


FIG. 71.—Poor workplace layout—operator must stoop to obtain material from container on floor.

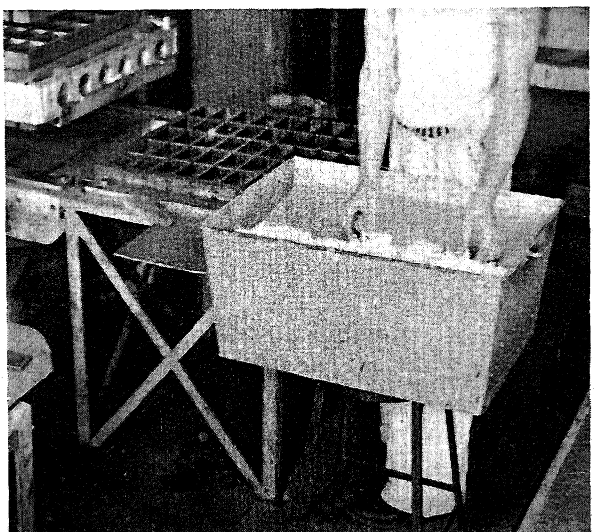


FIG. 72.—Better workplace layout—material may be secured without stooping.

When an analysis is made of a specific operation, one of the most glaring faults commonly encountered lies in the arrangement of containers of raw and finished material. If the placement is left to the operators, a body motion will often be used for getting or laying aside material, because the operator sets the material containers on the floor or the bench or in some other place that is available but not particularly convenient. Figure 71 illustrates a condition of this kind. The operator has placed a box of unfinished material on the floor beside his press. Every time he gets a part, he must bend his body, or in other words, must make a fifth-class motion. If before beginning the operation he were to place a stool beside his press and set the raw-material box on it as shown in Fig. 72, he could then get the parts with a fourth-class motion. Thus, the time required for the element "get part" is reduced, and fatigue is partly eliminated.

Put Away.—The put-away elements usually consume less time than the make-ready elements. Tools are put away, the setup is torn down, and the workplace is more or less thoroughly cleaned up. Usually, some of the put-away elements can be combined with some of the make-ready elements for the next operation. Tools for one operation, for example, may be returned to the toolroom when the tools for the next operation are obtained. The procedure that will prove most economical for the put-away elements will depend to a large extent upon the manner in which the make-ready elements are performed.

Where a number of similar operations are performed on a machine, it is sometimes possible to use the same or part of the same setup on two or more jobs. A part that is common to several assemblies may be ordered separately for each and appear on several different orders. If these orders are grouped, one setup will care for them all. Again, in milling-machine work, for example, it may be possible to use the same cutter for several different jobs. The elements of "get cutter from toolroom," "place cutter on machine," "remove cutter from machine," and "return cutter to toolroom" will thus be performed but once for the several jobs.

Where possibilities of this sort exist, provision should be made when setting up the make-ready and put-away routine so that the economies will be made. If the operator does not know what job he is to do next, if he must completely tear down his setup

before going for another job, and if neither the foreman nor the dispatcher attempts to group similar jobs, advantage cannot be taken of partial setups. This is wasteful, of course, and every attempt should be made to secure the benefit of partial setups. Whether or not the operator is paid for the complete setup or only for that part which he actually makes depends upon the difficulty in controlling setups and upon whether or not the saving is due to the operator's own initiative.[1] In either case, more time is available for productive work which is a distinct gain.

Questions on Tool Equipment.—The tool equipment used to perform the operation may logically be considered at the same time as the setup, for the two are closely related. The following questions are the sort that will lead to suggested improvements:

1. Is the machine tool best suited to the performance of the operation of all tools available?
2. Would the purchase of a better machine be justified?
3. Can the work be held in the machine by other means to better advantage?
4. Should a vise be used?
5. Should a jig be used?
6. Should clamps be used?
7. Is the jig design good from a motion-economy standpoint?
8. Can the part be inserted and removed quickly from the jig?
9. Would quick-acting cam-actuated tightening mechanisms be desirable on vise, jig, or clamps?
10. Can ejectors for automatically removing part when vise or jig is opened be installed?
11. Is chuck of best type for the purpose?
12. Would special jaws be better?
13. Should a multiple fixture be provided?
14. Should duplicate holding means be provided so that one may be loaded while machine is making a cut on a part held in the other?
15. Are the cutters proper?
16. Should high-speed steel or cemented carbide be used?

[1] For a discussion of this subject see Allowed Time in "Time and Motion Study and Formulas for Wage Incentives," 2d ed., by Lowry, Maynard, and Stegemerten.

17. Are tools properly ground?
18. Is the necessary accuracy readily obtainable with tool and fixture equipment available?
19. Are hand tools pre-positioned?
20. Are hand tools best suited to purpose?
21. Will ratchet, spiral, or power-driven tools save time?
22. Are all operators provided with the same tools?
23. Can a special tool be made to improve the operation?
24. If accurate work is necessary, are proper gages or other measuring instruments provided?
25. Are gages or other measuring instruments checked for accuracy from time to time?

Because of the wide variety of tools available for different kinds of work, this list could be extended almost indefinitely with specific questions. Foundries, forge shops, processing industries, assembly plants, and so on all have different kinds of tools, and different questions might be asked in each case. The list given above, drawn up principally and by no means completely for machine work, will indicate the kind of searching, suggestive questions that should be asked. A special list might well be drawn up by each individual plant to cover the kind of tools that might be advantageously applied upon its own work.

Tool Design.—The matter of tools is one that has received a good deal of attention, because a good tool is necessary to do a good job. Therefore, tools that function properly are found on the majority of operations that the methods engineer studies. If the tool did not function properly, it would not be used. Of course, in some shops where the matter of tools does not receive the proper attention, operations are encountered on which the operator is turning out passable work in spite of his tools rather than because of them.

For the most part, however, it may be said that the tools do function properly from the standpoint of the finished job. Whether or not they function properly from a motion-economy standpoint is another matter. The tool designer is usually more concerned with making a tool that will do a certain job than he is with the motions that will be required to operate it. Therefore, unless he has made a study of the principles of methods engineering or has had the importance of motion economy

impressed upon him in some other way, it is probably safe to say that the motions required to operate the tool are the last thing he thinks of.

As a result, tools are designed and built that require much more time to use than they should. The common machine vise is a good example. A vise similar to that shown in Fig. 44 of Chap. X is standard in most shops at the present time. Parts are clamped in the vise by turning up a screw. To hold them securely, the vise handle often has to be hammered with a mallet. Loosening the vise is an equally lengthy operation.

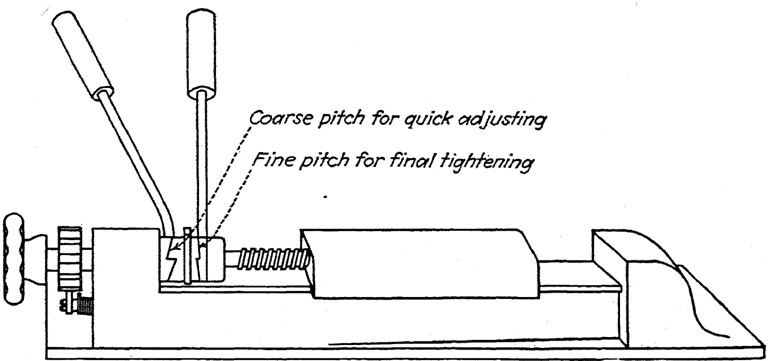


Fig. 73.—Machine vise tightened by cam-actuated mechanism.

The quick-acting vise illustrated by Fig. 73 is far superior. On machining operations where the cutting time is short, it will save 20 to 40 per cent of the total operation time. The jaws of the vise are cam-actuated. They are tightened by moving the two levers in opposite directions which conforms to the principles of motion economy. They hold securely without hammering on the levers. They are adjustable to a variety of sizes of work. In short, they possess many real advantages over the standard vise.

Suggestions that will improve the quickness of operation of tools should be made to tool designers as they are conceived. If they are presented with a summary of the yearly saving in dollars and cents that they will effect, interest in better tool design from a use-time standpoint will be aroused. This is very desirable, for tool designers as a group are clever and ingenious, and if the importance of reducing the time required to

operate tools is clearly demonstrated, they will be able to assist materially toward this end by producing more suitable designs.

Hand Tools.—There is a tendency to pay too little attention to the hand tools used upon even the more repetitive operations. To many, a screw driver is a screw driver, and if it fits the slot in the screw to be driven, it is considered satisfactory.

This is far from being the case, however. Screw drivers vary widely in design, and some are more suitable than others. Figure 74 is a photograph of all the types of screw drivers that were found in a plant employing 10 people, all doing the same class of

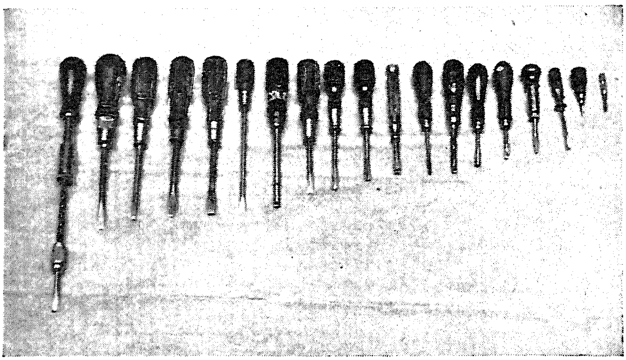


Fig. 74.—Variety of screw drivers found in small plant employing ten operators on light assembly work.

assembly work. A glance shows that the screw drivers could not all be equally satisfactory.

Screw drivers come in a number of different styles. There are the solid screw drivers, the ratchet screw drivers, the spiral screw drivers, and the various types of power-driven screw drivers. Even the variation among screw drivers of a given type is tremendous. They vary in size, of course, but in addition they vary in about every other way imaginable. The handles vary in diameter, length, cross section, shape, and nature of gripping surface. Points are wide, narrow, blunt, sharp, taper toward the point like a wedge, or are narrower right above the point than at the point. A lately introduced type has a special point to fit a special screwhead which offers many advantages.

When all these factors are considered, the wide variation in even such a simple tool as a screw driver becomes apparent.

There is, of course, one screw driver that is better for a given application than any other. For medium work with the conventional screwhead if a solid screw driver is to be used, the one with the largest cylindrical handle which can be comfortably grasped by the operator should be chosen. The handle should, of course, be fluted to prevent slipping. The diameter of the handle will vary with the size of the operator's hand, but two or

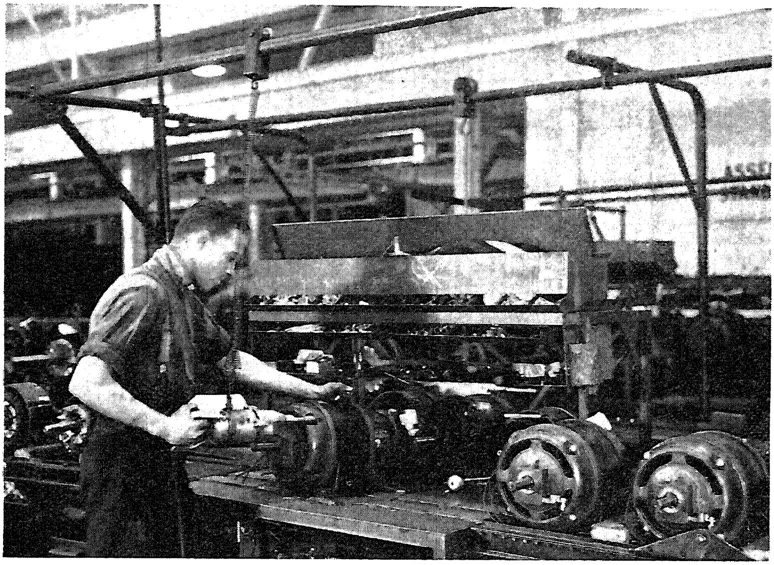


FIG. 75.—Power screw driver fitted with guide to minimize time required to position screw driver in slot.

three standard sizes are sufficient for most hands. The diameter of the handle should be large, because the larger the handle within the limits of the human hand, the more easily can a given torque be applied. To prevent slipping, the point should not be wedge-shaped but should be slightly larger at the point than just above it. Few screw drivers commonly encountered in industry meet these simple specifications.

If many screws have to be driven, a ratchet, spiral, or power-driven screw driver can often be used to good advantage. If many screws of the same size are to be driven, a piece of hardened tubing slipped over the end of the screw-driver point will make

it much easier to locate the screw driver in the slot. Figure 75 illustrates a power screw driver fitted up in this way.

The same sort of searching analysis can be made for every type of hand tool used. Wrenches, hammers, chisels, saws, scissors, knives, pliers, and drills all come in a great variety of styles. Standardization on a limited number of the better styles within a plant will tend to prevent the use of the more inefficient tools. Tests must be made to determine which styles are actually the most efficient, however, for the judgment of the operators cannot be relied upon. A man will prefer a certain tool because of its apparent strength, the color of its handle, its pleasing appearance, or its familiarity. Unbiased tests are much more reliable.

Judgment must be used, of course, in determining the amount of time that can economically be spent in analyzing the tools used on any one job. Unless a job is highly repetitive, it will not pay to try to discover the best screw driver for that particular job. Instead, the whole subject of hand tools including screw drivers may be investigated in a general way, and good tools may be adopted for standard use. The tool supply should be plentiful, for it is not uncommon to see operators not only using the wrong size of tool, but also using a chisel for a hammer or a screw driver for a crude chisel merely because the proper tool is not available. An insufficient supply of proper tools may reduce the amount expended for tools, but it will prove costly in the long run.

CHAPTER XVII

OPERATION ANALYSIS—TEN COMMON POSSIBILITIES FOR OPERATION IMPROVEMENT

Item 7 of the analysis sheet lists 10 possibilities for operation improvement. At least one or two of these usually apply to every job studied. Hence, although several of the items should have been covered previously, particularly during the analysis of the setup, tools, and workplace layout, the list as given should be gone over carefully on each operation analyzed. If each possibility is viewed open-mindedly, applications are almost certain to be found.

There is the danger, of course, that after a number of analyses have been made, the 10 possibilities will be given a mere perfunctory consideration. It is much easier to write "not practical" after each possibility than it is to conceive a method which will take advantage of the possibility for improvement and then to take the action necessary to have it put into effect. A good analyst, however, really interested in trying to improve operations, will realize the importance of the list and will give the 10 points proper consideration. Those who are inclined to treat analysis as a routine matter will in all probability never excel as analysts in spite of any guides and direction that may be given.

Gravity Delivery Chutes.—Gravity delivery chutes are useful for bringing material close to the point of use, thereby shortening the motions required to obtain the material. The usual arrangement consists of a hopper that will hold a reasonable supply of material with an opening at the bottom through which a few pieces may pass. Material may be removed directly from the opening at the bottom of the hopper. If the workplace is crowded, the hopper may be set out of the way and a chute provided between the bottom of the hopper and the point of use along which the parts may slide by gravity. Figure 76 illustrates a typical hopper arrangement. Molded motor bases are dumped into the hopper periodically. They are removed one

at a time from an opening in the bottom as they are required by the operator.

If parts are of a suitable shape, special delivery devices may be built that are more effective than the common chute. Small, uniform parts with no projections may be handled in an arrangement that delivers the parts at the bottom in predetermined quantities. The coin holders used by street-railway conductors, newsboys, and others who must make change frequently are a

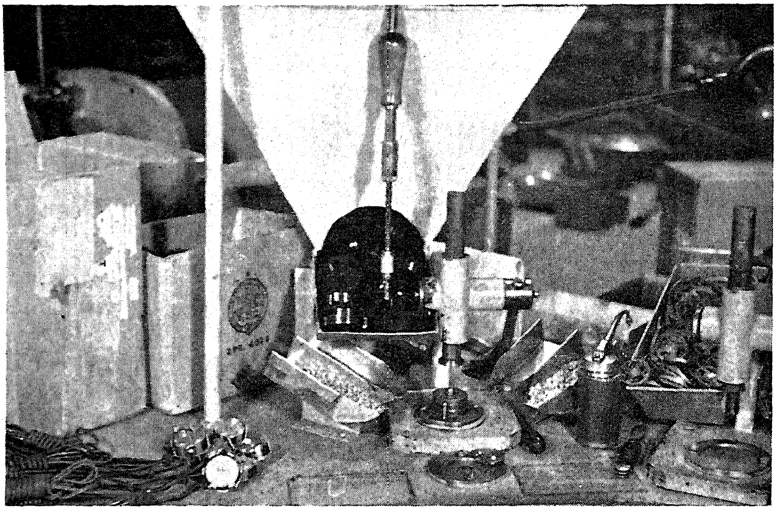


FIG. 76.—Gravity hopper which stores large quantity of parts and delivers them as required at the point of use.

well-known example of this sort of delivery device. Figure 77 shows a holder for motor parts that acts on the same principle. Parts are stacked in the holder. They are removed at the bottom three at a time by a simple sliding motion.

Many parts are by no means free from projections or even symmetrical in shape. The design of chutes and hoppers that will handle irregular parts is more difficult, and considerable cutting and trying may be necessary before an arrangement can be devised that will deliver parts uniformly at a given point and will neither jam nor overflow. If the chute is used in conjunction with moving machinery, the delivery problem is much easier. Even the smoothest running machine has a certain

amount of vibration, and if the chute is rigidly attached to some part of the machine, the vibration will cause the parts to move slowly and uniformly down the chute and even around bends.

Figure 78 shows an application of this principle. The chute is used in conjunction with a trimming machine for a leather

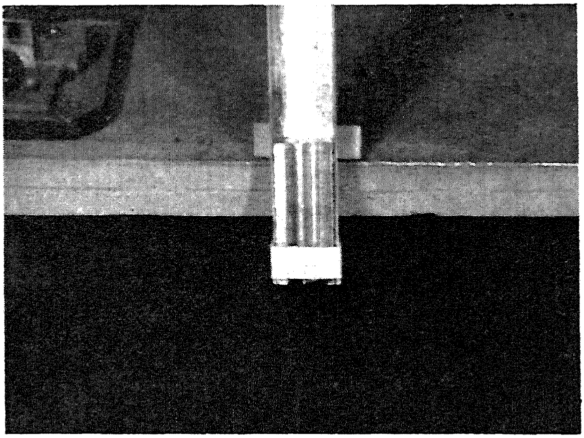


FIG. 77.—Holder for flat parts which delivers parts in predetermined quantities.

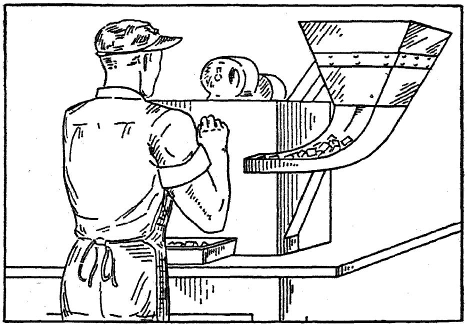


FIG. 78.—Gravity delivery chute with movement of parts actuated by vibration of machine.

product. As originally designed, the parts tended to jam in the hopper. Removing the key of the jam brought a rush of parts which sometimes overflowed the sides of the chute. The parts did not slide easily, and, therefore, the chute had to be steep. An angle sufficient to overcome starting friction was too steep when the parts were in motion, and the parts shot down so quickly

that they were continually falling to the floor. These difficulties were overcome by slight design changes, but principally by attaching the chute to the machine so that the vibration from the machine kept the parts in motion. After this, the parts fed uniformly down the chute and arrived without interruption at a point where they could conveniently be grasped by the operator.

Drop Delivery.—Drop delivery, as the name implies, consists of getting rid of a part by dropping it. It is used when placing finished parts aside. Sometimes, it is possible to arrange a setup in such a way that the finished part falls off into a container or chute as it is completed, and the operator does not have to

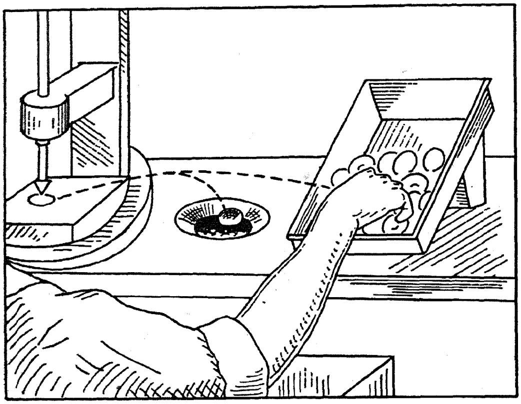


FIG. 79.—Proper arrangement of finished-material disposal and raw-material containers for drop delivery.

handle it after completing work upon it. For example, after completing the trimming operation on the machine shown by Fig. 78, the operator merely opens his fingers, and the finished part falls into a box placed directly beneath the cutter. On operations where the finished part must be carried aside by the operator, drop delivery is still obtained if the part is carried over a container or a chute and is released by opening the fingers as the hand continues on its way to the next point, which is usually the raw-material supply. Not all parts can be dropped, of course. Fragile, brittle, or soft parts would be damaged if dropped with any appreciable jar. Even with parts of this kind, however, drop delivery can sometimes be used if the parts are dropped onto some sort of soft, yielding surface. A canvas chute

may be provided, for example, which first breaks the fall of the part and then permits it to slide gently into a container.

When drop delivery is employed, the relative position of the raw- and the finished-material containers is important. Many times workplace layouts are encountered in which the raw material is close to the operator and the finished material farther away. This is incorrect. The finished material should be closer to the operator and the raw material farther away and in the same line. Figure 79 illustrates how this should be arranged.

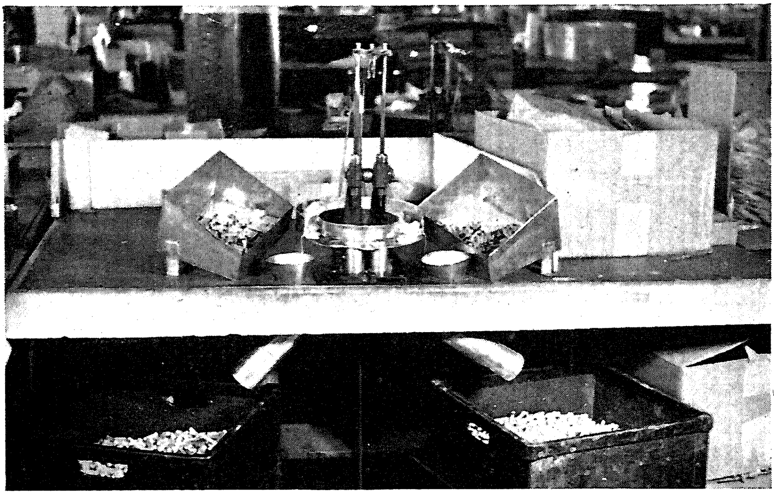


FIG. 80.—Workplace layout designed for drop delivery with funnels guiding parts through small openings in bench.

When the operator finishes work on a part, he grasps the part. He moves toward the raw-material container and drops the part in the finished-material container on the way. With a little practice, he can do this without hesitation. Finished material is laid aside and raw material is obtained with two motions, one over to the raw-material container and one back to the work point. If the position of the material containers is reversed, three motions will be required, one to the finished-material container where the part is dropped, one to the raw-material container, and one from the raw-material container to the work point.

In order that parts may be dropped during a motion without hesitation, the object into which they are dropped must be large enough so that there is no danger of missing it. If the container itself is small or if the part must pass through a small hole in the bench, a funnel should be provided to make it easy to drop the part in the desired location. Figure 80 shows an application of this principle.

Drop delivery suggests that the part falls away owing to the force of gravity. The same effect may be obtained by the use of

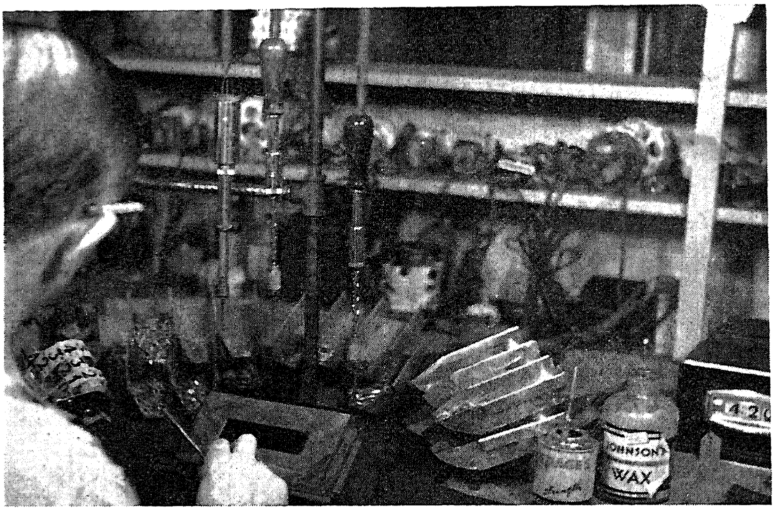


FIG. 81.—Tools suspended over the workplace on springs move aside when released by operator.

springs that carry the released part aside, usually in an upward direction. The most common application of this arrangement is in the suspension of tools above the workplace, as shown in Fig. 81. The tools are hung on a spring. After the tool has been used, it is released by opening the fingers. The spring carries it away without further attention on the part of the operator.

A similar application of this principle may be made to the levers of small hand-operated arbor presses. Figure 82 shows such an application. When the handle of the press is released after the operation has been performed, a spring carries it out of the way and raises the arbor. The hand of the operator at the

point of release is thus near the point where it must next go, instead of some distance away as it would be if the hand had to return the press lever to the aside position.

Methods Used by Two or More Operators.—The necessity of and the reasons for analyzing the methods used if more than one operator is working on the same operation have already been mentioned in Chap. X. The importance of this point cannot be overemphasized. If no detailed instruction has been given, in at least 95 per cent of all cases observed by the authors, different operators on the same job will use different methods, even if the

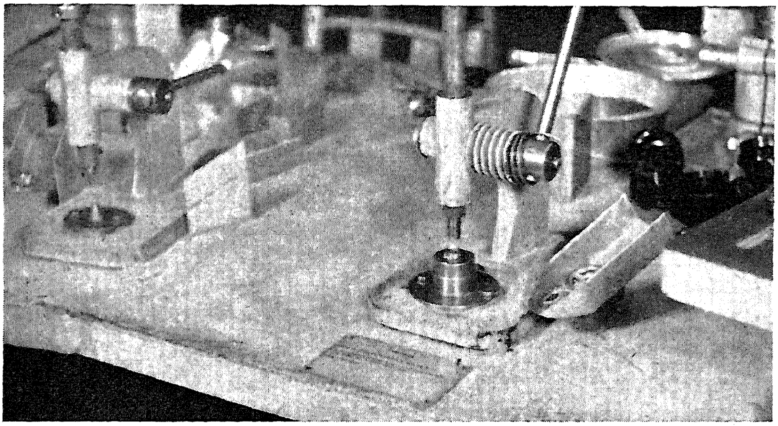


FIG. 82.—Hand arbor press fitted with spring to move handle aside by drop delivery.

operation is fairly simple. The methods will all resemble each other, to be sure, but the trained observer will be able to detect many minor differences, and it is these differences that account for variations in production, fatigue, and quality of work.

As a matter of fact, where no specific instruction regarding proper methods has been given, it is not uncommon to see the same operator using two or three different methods on the same operation. Questioning fails to reveal the reason for this. Most operators do not seem to realize that they are using different methods. They have not been taught to regard their job as a series of elemental motions, and therefore an extra motion or two may be made without conscious recognition.

Before chutes were provided for the trimming machines shown in Fig. 78, the operators had different methods of performing the operation. The operation consisted of picking up a leather part, trimming it, and laying it aside. Two operators working side by side, day in and day out, differed in the method in the following respects. Operator *A* picked up a part with his right hand from a box located to the right of his machine while finishing the trimming of the preceding part with his left hand. Because his eyes were on the part and cutter, his right hand had to search before it could grasp the next part. The part was often picked up in the wrong position for trimming, and it had to be pre-positioned on the way to the cutter. He released the trimmed part as soon as it was completed and dropped it into a box which was located directly beneath the cutter.

Operator *B* held the part being trimmed with both hands. After the last trimming cut was started, he dropped his eyes to the raw-material supply which was located directly beneath the cutter. By the time the trimming was finished, his eye had located the next part to be trimmed. Thus, he was able to drop his right hand and pick up the part without search and transport it to the machine with a minimum of pre-positioning. When the right hand was reaching for the next part, the left hand tossed the finished part into a box, using a wrist motion.

The entire operation required only a little over 2 seconds to perform, but the methods employed by the two operators differed in nearly every respect. Neither method was the best method, for subsequent motion-study developed a method that was superior to both. The new method was based, however, upon the best features of both the methods in use plus certain developments made by the methods engineer.

On repetitive work of the nature described, considerable difference is found in the output of different operators doing the same operation. The usual tendency is to attribute this to differences in skill and perhaps effort. In reality, however, the difference is usually primarily due to a difference in method. The high producers have the best methods. These may have been developed as the result of long experience, or they may have been hit upon the first day on the job. The low producers have poor methods. These operators may be new to the work, or they may be old operators following a poor method from habit.

With proper operator instruction, this condition will not exist. If the best existing method is first recognized and then taught, all operators but the obvious misfits may be raised to the levels of the highest producers. This can be done by any supervisor who is able to recognize different methods when he sees them and who realizes the difference that minor variations make. If he is sufficiently interested to decide which of several methods is best and to teach that method in detail to each operator in the department, he can raise the performance level of his department within a short time without any outside assistance.

It must be recognized, of course, that it is not always easy to teach operators new methods. Old methods, because of constant repetition, become habitual, and habits are hard to change. Very often, the easiest and best method will seem harder and slower to an operator than his own method. His production will fall off at first, and he will want to return to his own way of doing things. Patience and persistence on the part of both the operator and his instructor will overcome these difficulties, however, and a better performance and higher earnings will eventually result.

Chairs for Industrial Workers.—The subject of chairs for industrial workers has received a good deal of attention, and most progressive concerns have tried to do something along these lines. Interest in the subject is usually not sustained, however, and therefore the analyst often finds room for improvement. Many chairs designed for industrial use have been placed upon the market, some of which are good. Because of the expense involved, chairs are usually purchased a few at a time. As a result, a given plant may have some chairs that are good, some that are fair, and some that are definitely poor.

To minimize fatigue, work should be done alternately seated and standing. Although it is less fatiguing to work seated than standing, even the seated position becomes tiring after long periods of time. Therefore, a workplace arrangement that permits the operator to vary his position from time to time is the best from the standpoint of fatigue.

In order to permit the use of the same motions seated or standing, the height of the chair must be such that the elbows of the operator are the same distance from the floor when he is seated as when he stands. The proper height of the workplace should be determined while the operator is standing.

This is the ideal condition, and like many ideals, is difficult to attain under everyday conditions. Operators vary in size which makes adjustable chairs and even adjustable work-station heights necessary. Where two or more shifts use the same equipment, the problem is further complicated. A tall operator may work a given operation on one shift and a short operator on the next. For example, a certain plant operated a large sewing department on a two-shift basis. When the first shift finished work, all the operators were required to leave the department. Then, after a signal was given, the second-shift operators entered. The first few minutes were occupied by a confused search for suitable chairs. The sewing machines were all the same height from the floor, and so each operator had to search for a chair that was adjusted so that it would enable her to assume a fairly comfortable working position. Considerable time was lost in starting work, and it was not always possible for an operator to find a suitable chair.

Variable conditions of this sort may best be met by providing equipment that is suitable for a certain size range. Chairs may be adjusted for several classes of operators as very short, short, medium, tall, and very tall. If the chairs are marked as to class and the operator is informed of the class to which she belongs, she will have no difficulty in locating a proper chair at the beginning of the shift, provided that a sufficient number of all classes is available.

The height of the workplace is a point that has received too little attention throughout industry. Benches are made to a standard height. Thus, when an operator stands at the bench, if he is short, he stands on a box or a platform if he can get one. If he is tall, he stoops and as a result has an aching back at the end of the day. Conditions of this sort should be corrected wherever found. A slight change in the height of a workplace will often result in more production of a better quality and a more satisfied and less fatigued operator.

An industrial chair, besides being adjustable for height, should have a wide seat from side to side and an adjustable back rest. If, however, the seat is wide from front to back, many operators will sit on the front edge of the chair and will not use the back rest. This apparently is because, when one is sitting far back on a wide seat, the front edge of the chair presses the underside of

the thighs, cutting off circulation from the feet and legs and causing general discomfort. A tired back seems preferable, and so operators sit on the front edge of their chairs. This condition may be avoided by providing narrow seats not greater than 13 inches from front to back.

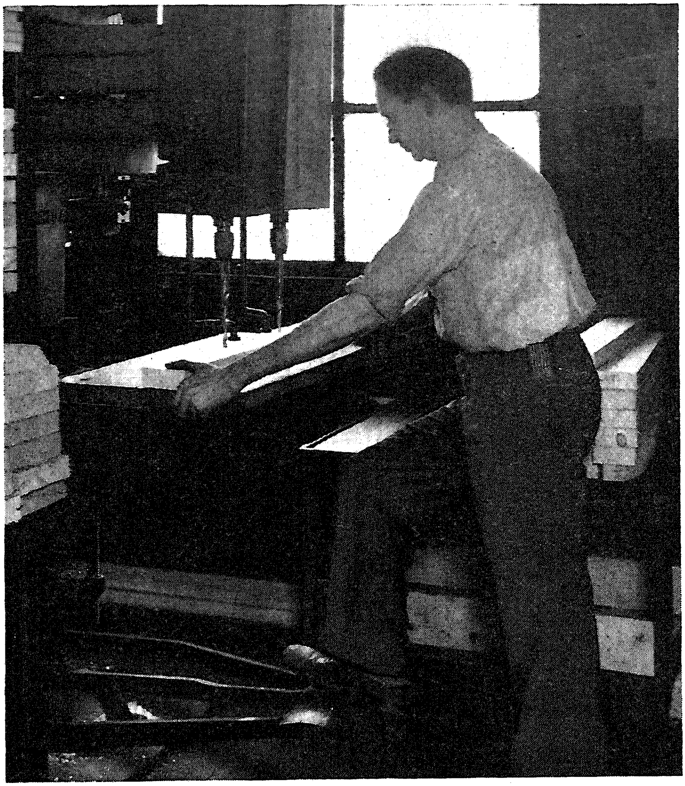


FIG. 83.—Foot-operated drill press.

Ejectors and Quick-acting Clamps.—The possibility of improving jigs and fixtures and of providing ejectors, quick-acting clamps, and other time-saving devices should have been considered when the tool equipment was analyzed. The point is so important, however, that it is brought up for consideration again under item 7 of the analysis sheet so that it will not be overlooked. Quick-acting clamps, for example, materially reduce the time

required to fix a part in a holding device. Ejectors kick the part out of the holding device and make the removal of the part easier.

Foot-operated Mechanisms.—Any time that an operation can be performed by parts of the body other than the hands, it should be so done, if there is other work that the hands can perform at the same time. In this way, the hands are relieved of performing certain motions, and time is saved. If, however, there is no other work for the hands to do, there is usually no point in transferring operations to the feet.

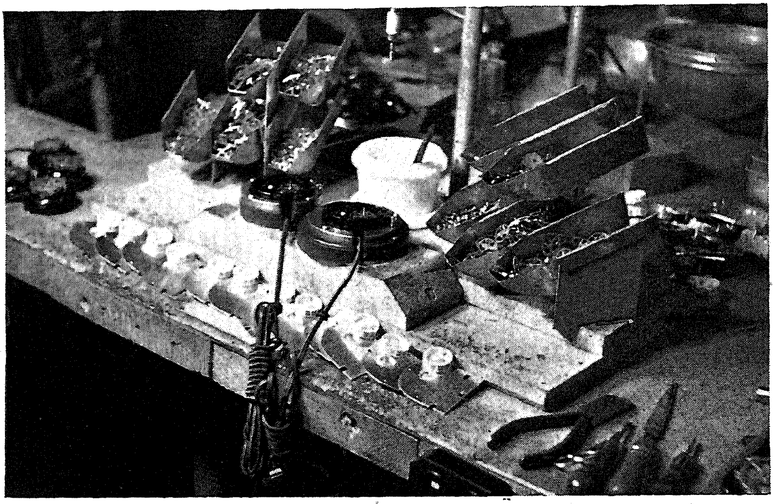


FIG. 84.—Typical two-handed setup for electric-clock motor assembly.

The foot-operated drill press, Fig. 83, is a common example of a foot-operated mechanism. The operator works the drill spindle by a foot pedal, leaving both hands free to place drilled parts aside and to get other parts to be drilled. Foot-operated ejectors are sometimes advantageous, as they leave both hands free to grasp the part as it is ejected. Vises may be opened and closed by foot with a considerable saving of time. When chips or cuttings must be removed from a fixture at the end of an operation, an air jet built into the fixture and controlled by a foot-operated valve may be provided. The possibilities for employing foot-operated mechanisms are many, and the analyst should constantly be on the watch for them.

Two-handed Operation.—Two-handed setups which permit the use of motions made simultaneously by both arms moving in opposite directions over symmetrical paths are highly desirable, because they yield far greater output with the same or less expenditure of energy than do setups on which one hand only is able to work effectively.

Figures 84 and 85 illustrate typical two-handed setups for widely different types of work. Both of these doubled production

FIG. 85.—Typical two-handed setup for packing toy building blocks.

when installed. Figure 80 also shows a two-handed setup. Although when two-handed setups are once devised they are fairly simple to operate, it requires considerable ingenuity and a thorough understanding of the principles of motion economy to make them correctly. Two-handed-operation setups are usually made only after detailed motion study. The possibility of making such a setup should be considered during the analysis of all operations, however, for throughout the analysis process, the desirability of a subsequent more detailed study must be kept in mind.

Normal Working Area.—The concept of normal and maximum working areas has been discussed in the preceding chapter under the head of "The Workplace Layout." If the arrangement of tools and material was not considered during the analysis of item 6, it should be studied during the analysis of item 7, for the proper arrangement of the workplace is highly important to effective performance.

Layout Changes and Machine Coupling.—As the result of detailed analysis, the possibility of coupling machines may have occurred. Machine coupling or multiple machine operation is possible when the operator is idle during part of the operation cycle, usually because a machine is doing the work without attention on his part. The idle time can often be utilized in running another machine if the second machine is located near the first.

If no machine is available near by, it may be desirable to change the layout and move one or more machines about. It is usually best to avoid making many minor layout changes separately, for if all factors affecting the department as a whole are not considered, the layout is likely to become inefficient. Unless a change is obviously desirable and easy to make, it is better to accumulate suggestions for change until sufficient are at hand to make a detailed layout study advisable.

The possibilities for machine coupling are brought out by man and machine process charts; construction of this type of chart will be discussed in the next chapter. Plant layout is a study in itself. The general procedure for making layout studies will be described in Chap. XIX.

Utilization of Improvements Developed for Other Jobs.—Each operation analysis should not be regarded as an entirely new investigation. Many different operations present points of similarity; if a good method has been worked out for one operation, parts of it may often be applied to another. The chute illustrated by Fig. 78, for example, was devised for a leather-trimming operation. The same sort of chute is equally advantageous on the next two operations performed on the part, or "ink" and "burnish."

When a device has been developed that is found to be applicable to a number of jobs, it may be made up in quantities and stocked so that it is always available for use. For example, a

container suitable for holding small parts for assembly work was developed in a certain plant. The container was found to be far superior to anything else in use, since it occupied a small space on the bench, made grasping of parts easy, and embodied the principle of the gravity delivery chute.

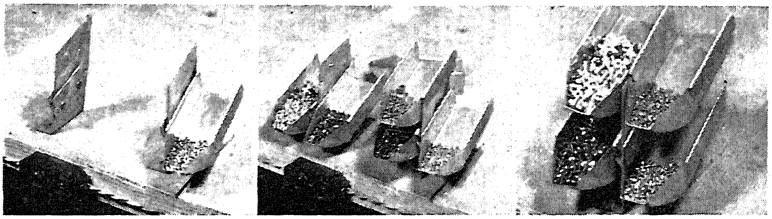


FIG. 86.—Standard container for small parts and support which holds one, two, three, or four containers.

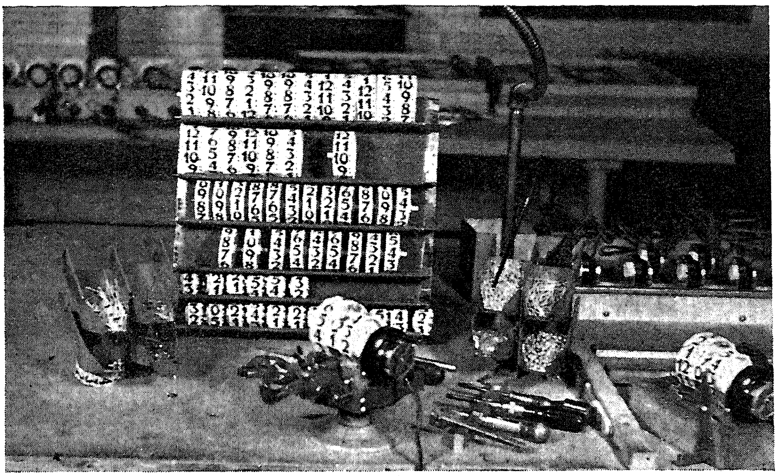


FIG. 87.—Effective layout quickly set up by using standard material containers.

The design of the container was, therefore, adopted as standard. Containers were made up in quantities, together with a support that would hold one, two, three, or four containers, as shown by Fig. 86. As a result, whenever a new operation is set up, it is a simple matter to screw one or more supports to the bench and attach the proper containers. With this equipment in stock, an effective workplace layout such as that shown by Fig. 87 can be set up in a very few minutes.

CHAPTER XVIII

MAN AND MACHINE PROCESS CHARTS

In certain types of operations, the operator's time is not fully occupied during the operation cycle. The nature of the operation is such that, as far as a certain portion of it is concerned, the operator might just as well not be there. The most common example of this occurs on machine work. When the machine makes a cut under power feed, the operator stands by with nothing to do until the end of the cut is reached.

The same condition occurs in many other kinds of operations. Whenever an operation is temporarily under the complete control of the machine or whenever the operator must wait for a part to heat or cool, a chemical reaction to take place, or the like, idle time exists. In the interests of effective production, this idle time should be utilized.

The first step in undertaking the elimination of idle time from an operation cycle is to determine exactly when the idle period occurs, how long it lasts, and what its relation is to the part of the cycle during which the operator is occupied. This may be shown clearly by constructing what is commonly known as a "man and machine process chart." The chart owes its title to the fact that it is most frequently used for machine studies, but it is equally useful for any other type of work where idle time occurs.

Constructing the Chart.—The object of the man and machine chart is to show the exact relation between man time and machine time. Machine time may, of course, be considered to be any processing time that the operator does not control. Because it shows the relation between two or more separate but related operation cycles, this type of chart may also be used to study the work of several operators on a group operation even though no machine is involved. The process charts, Figs. 24 and 25 of Chap. VI, constructed to study the relation between passenger time and operator's time on a one-man streetcar are a special form of man and machine chart.

Either blank or cross-section paper, 8½ by 11 inches, may be used for the construction of the man and machine chart. The chart is identified at the top of the paper. The elements of the operation are listed in a vertical column. Then, in parallel vertical columns, the time the man works and the time the machine works are indicated. If more than one machine is used, a separate vertical column is assigned to each machine. The chart is drawn to scale so that the relative time consumed by each element may be ascertained at a glance.

In Chap. X, an analysis sheet filled out for a simple milling-machine operation was shown, and the steps of the analysis were described. It was seen that the analyst recognized the possibility for multiple machine operation almost from the start. He first considered working the milling and drilling operations together but discarded this idea as impractical under existing conditions. He saw, however, that although it was undesirable to place a drill press by a milling machine, it would be quite practical to place two milling machines together in such a way that one man could operate both machines. When he reached a consideration of possibility 9 under item 7, therefore, his next step was to construct a man and machine process chart to see just how this would work out.

The elements of the milling-machine operation and the allowed time for each are as follows:

Element Description	Allowed Time, Dec. Hr.
Pick up small part from table	0.0007
Place in vise	0.0009
Tighten vise	0.0020
Start machine	0.0003
Run table forward 4 in.	0.0012
Engage feed	0.0003
Mill slot	0.0080
Stop machine	0.0015
Return table 6 in.	0.0017
Release vise	0.0013
Lay part aside in tote pan	0.0009
Brush vise	0.0009

Figure 88 shows the man and machine chart that was constructed from these data. It shows the elements, man time and machine time, and emphasizes the fact that the operation is far

from being satisfactory. When the man is working, the machine is idle, and when the machine is working, the man is standing

MAN AND MACHINE CHART
MILL SLOT IN BRASS CLAMP-DWG.822304
No.2B MILWAUKEE MILLING MACHINE

	Man	Machine
Pick up small part from table	0.0007	
Place in vise	0.0009	
Tighten vise	0.0020	
Start machine	0.0003	
Run table forward 4"	0.0012	
Engage feed	0.0003	
Mill slot		0.0080
Stop machine	0.0015	
Return table 6"	0.0017	
Release vise	0.0013	
Lay part aside in totepan	0.0009	
Brush vise	0.0009	
Sub totals	0.0117	0.0080
Time per piece		0.0197

FIG. 88.—Man and machine process chart—milling-machine operation.

watching it. The desirable condition is, of course, to have both working steadily. Preliminary analysis shows that the machine

works 0.0080 hour and the man 0.0117 hour. If two machines were provided, the man could work continuously. It would then require 0.0117 hour per piece plus 0.0008 hour to turn from one machine to the other, or a total of 0.0125 hour to produce each piece. This is an improvement over the first method with its time of 0.0197 hour per piece, but each machine would be idle 0.0125 − 0.0080 = 0.0045 hour per piece. Thus, the necessity for adopting some of the other suggestions for improvement that were uncovered during the course of the analysis is emphasized.

Accordingly, several of the recommended changes are made. A vise with a quick-acting cam-actuated clamp is provided, thereby reducing the time to tighten and release vise to a total of 0.0006 hour. The machine is allowed to run until the clamp has been returned past the cutter and is then stopped while the table is being run still farther back so that the vise is out of the way of the cutter. A trial shows that this does not affect the finish of the slot enough to spoil it for the purpose for which it is to be used, and the "stop-machine" element is thus eliminated, reducing the operator's time by 0.0015 hour. An ejector is provided which kicks the part out of the vise as it opens, and the part slides down a chute to the tote pan. Thus, the "lay aside part in tote pan" element is eliminated, and 0.0009 hour is saved.

These changes reduce the operator's time by 0.0051 hour, or to 0.0125 − 0.0051 = 0.0074 hour. Thus, under the new setup, the machines operate continuously, and the operator has 0.0006 hour idle per piece or can work at a slower pace with less fatigue. The "brush-vise" element could be eliminated by attaching an air hose to the machine and arranging a foot control on the floor. The operator would step on the control as he opened the vise, and the chips would be blown out while he was picking up the next piece. Since the machines are working continuously, however, this change would only increase the idle time of the operator, and as his fatigue is not great on this operation, the change need not be made.

Typical Problem.—The operation just described is simple, and an experienced analyst could undoubtedly solve it mentally without the man and machine chart. Many problems are more complicated, however, and the charts are essential if the most efficient arrangement is to be made.

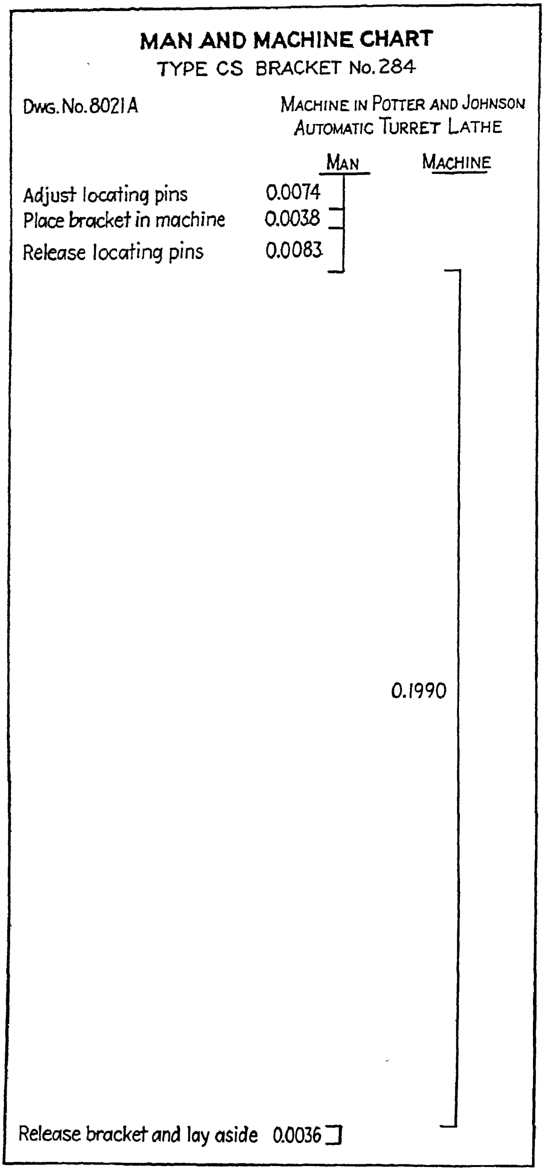


FIG. 89.—Preliminary man and machine process chart—bracket-machining operation.

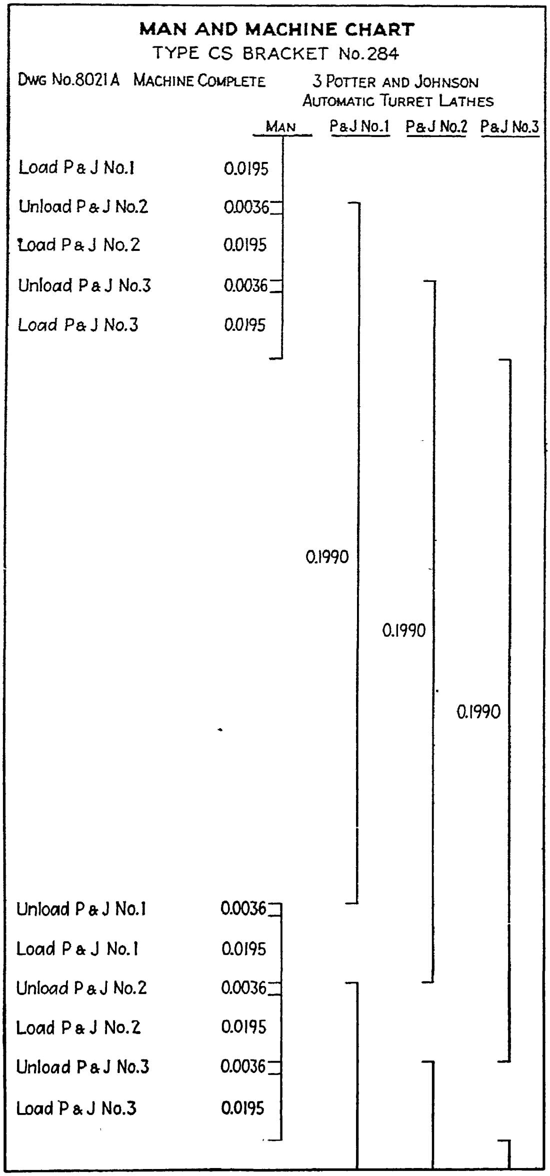


FIG. 90.—Intermediate man and machine process chart—bracket-machining operation.

For example, for a certain bracket machined on a Potter and Johnson automatic turret lathe, time study shows that it requires 0.0231 hour to load and unload the machine and 0.1990 hour to make the cuts. After the machine is loaded, the operation is entirely under the control of the machine, and the operator has nothing to do. The man and machine chart for this operation is shown by Fig. 89. The problem is to make a setup that will permit the operator to utilize the 0.1990 hour of idle time effectively.

Many different arrangements will probably be possible, but for a given set of conditions, there is usually one that is better than the others. For the bracket job, there are three Potter and Johnson lathes available. If these are all set up for bracket machining, the operator can run all three at one time. Even with this arrangement, however, an intermediate man and machine chart, Fig. 90, shows him to be idle 0.1528 hour for each three brackets machined.

The next operation performed on the brackets is a drill-press operation on which an allowance of 0.0535 hour is established. There is no power-feed drilling on this operation, and so the operator cannot do anything else while drilling.

The lathe operator may be given the drill press to run. If he drills two brackets to every three machined on the lathes, he will be idle $0.1528 - (2 \times 0.0535) = 0.0458$ hour per three brackets. If he drills three brackets to every three machined on the lathes, each lathe will theoretically be idle 0.0026 hour per bracket. The drill-press time value is the allowed time, however. By exerting better than average effort and by developing better than average skill, the operator will shorten this time and hence will be able to eliminate all idle time from the cycle.

The most efficient arrangement in this case, therefore, will be for one man to run three lathes and one drill press, machining three brackets per cycle. The man and machine process chart, Fig. 91, shows the sequence in which the operations must be performed to work most effectively.

Multiple Machine Operation on Miscellaneous Work.—The operations thus far described have been quantity operations. A sufficient number of pieces is produced to justify assigning special machines to these jobs only. When the setup is worked out and put into effect, it will remain in operation for weeks and even months.

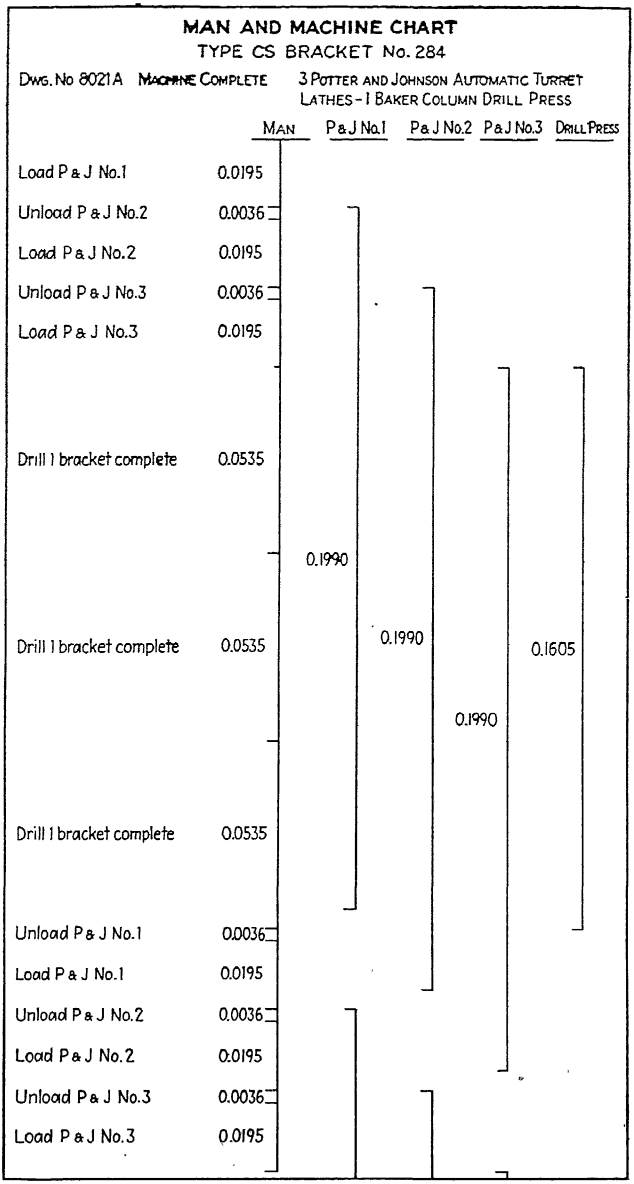


FIG. 91.—Final man and machine process chart—bracket-machining operation.

When work is of a miscellaneous nature, however, with jobs changing daily, machine coupling is more difficult although not impossible. Because of the rapidity with which operations change, it is impractical for the supervision to attempt to plan the work so that one operator can run more than one machine.

If, however, surplus machine equipment is available, two, three, or even four machines may be placed facing one another in such a position that one operator may run all of them. Whether or not the operator runs all machines or only one of them is left entirely to him. He is given a number of jobs to do and has several machines to do them on. If he is an operator who can plan effectively, he may be able, by working jobs with long cuts with jobs requiring short cuts, to keep all machines in operation most of the time. If he is unable to think ahead and to see possibilities of making combinations, he will not be able to turn out so much work.

Principles of Multiple Machine Operation.—Where machine coupling has never before been practiced, a certain amount of preparatory work must be done to overcome prejudices that are quite likely to exist. Where for years it has been the custom to have one man at each machine, operators may feel that they are being asked to exert themselves unreasonably if they are asked to work in a period when they would otherwise be idle.

There is little logic in this attitude. Other operators such as assemblers, welders, molders, fitters, and so on, work steadily all day as a matter of course. Outside of occasional necessary breathing spells if the work is heavy, they do not expect to be idle. There is no reason other than habit why machine operators should expect different rules to apply to them. As a matter of fact, on automatic screw machine work and certain special-purpose machines, one operator has tended several machines for many years. It is only when the principles of machine coupling are extended to lathes, boring mills, milling machines—machines for which the idea of machine coupling is new—that questions are raised. If this is likely to occur, however, the matter should be fully discussed with all concerned before the installation is made.

It should be made clear that machine coupling is not a speeding-up process. The operator is not asked to work more quickly and to rush about from machine to machine, but rather only to

occupy himself during a period when he otherwise would have nothing to do. In no case is he asked to exert an effort that is in any way detrimental to his own safety or physical well-being. When operators become accustomed to the idea of handling more than one machine, they usually have no objection to doing so, since no intelligent individual finds sitting or standing by a machine in enforced idleness a particularly interesting task. Rather, it is more interesting to try to keep several operations going simultaneously, getting the best performance from each.

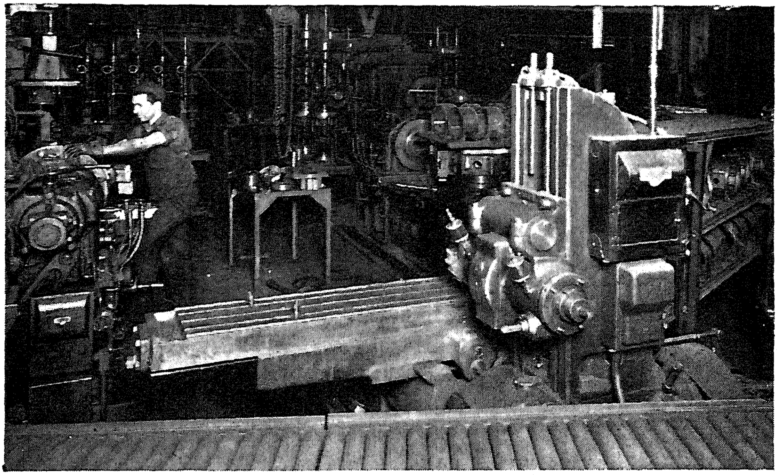


FIG. 92.—Multiple machine setup for machining electric-motor frames.

Quality is not impaired by this arrangement, since nothing that the man does after the cut is started in any way affects quality. The only precaution that should be taken is to make sure that the machine will not do any damage if the operator is forced to be away from it longer than the time required to make the cut. Most modern machines can be set to stop automatically at any desired point.

Operators who run more than one machine customarily receive a somewhat higher rate of pay than operators who run only one, the thought being that they have greater responsibility and hence are entitled to higher compensation. On miscellaneous work where the running of two or more jobs at one time is left to the operator, he is usually paid the full amount for each job under

the piece work or bonus plan used. Since the combining of jobs is left to the initiative of the individual, it is felt that he is entitled to the extra earnings, the employer being satisfied with increased production at the same overhead cost.

A typical production setup making use of the principles of machine coupling is illustrated by Fig. 92. Two different types of electric-motor frames are handled simultaneously in this setup, and one man runs all machines. The frames are delivered by the double-deck roller conveyer on the right to the milling machine in the foreground where the feet are milled. From the milling machine, one type goes to the automatic turret lathe on the right and the other to the automatic turret lathe on the left. The frames are bored and faced complete and are then placed on the double-width gravity conveyer above the turret lathe on the right for delivery to the double-spindle multihead drill press. Then I-bolt and setscrew holes are drilled and tapped on another drill press, and the foundation boltholes are drilled on the multiple-spindle drill press shown in the left background. This completes the machining cycles, and the frames are placed on a gravity conveyer in the left background not visible in the picture, for delivery to a press for pressing the core into position.

CHAPTER XIX

PLANT-LAYOUT PRACTICES

As the result of detailed operation analysis, suggestions are likely to be advanced concerning the improvement of plant layout. If a highly repetitive job is analyzed, the desirability of revising the layout may be demonstrated by the analysis of a single operation. If the work is of a more miscellaneous nature, although the analysis of an operation may develop suggestions for change, the layout is not usually revised unless and until the accumulation of a number of similar suggestions resulting from the analysis of other jobs indicates that a general layout study is desirable.

The arrangement of machines and other equipment in the best locations for economical manufacturing plays an important part in efficient plant operation. This fact has long been recognized by progressive industries. Larger organizations have found it profitable to set up a special department whose only duty is to study products and processes for the purpose of improving manufacturing layouts. Many smaller plants also recognize the importance of good layouts and from time to time review their equipment arrangements in supervisors' meetings or by special studies.

Development of Plant-layout Practices.—Although attention has been given to the subject of plant layout for a number of years, ideas in connection with what constitutes efficient arrangements have recently undergone radical changes, largely due to the viewpoint developed by methods engineers as the result of their detailed methods studies.

In the very early days of industry, little attention was paid to layout. Machines were arranged in long rows due to the use of line drives, and benches and other equipment were placed wherever there was room. The general appearance was crowded and chaotic. The movements of the operators were often hampered by poorly placed equipment and large piles of finished and

unfinished material. Material traveled up and down the length of the manufacturing space more or less haphazardly, and there was a great deal of back travel and lost motion.

As the principles of scientific management began to develop and the more progressive industries began to recognize the value of planning and systematic procedure, plant layout received more attention. In the course of time, certain principles were developed which were thought to conform with efficient plant operation. The most important of these were briefly as follows:

1. Raw material should come in at one end of the shop, and the finished product should emerge at the other end.
2. Aisles should be provided for transportation purposes and should be kept clear at all times.
3. Like machines should be grouped and arranged in straight lines or orderly rows.
4. Ample space should be provided around each machine for the placement of material.

The general appearance of layouts made in conformance with these principles was pleasing. A sense of orderliness and lack of crowding was attained, and it was felt for some time that work was done efficiently under such conditions.

Modern, detailed methods study, however, has shown that such arrangements are far from satisfactory and that many inefficiencies exist. Material travels farther than necessary; too much valuable floor space is used for storage purposes; there is a great deal of back travel; military lines cause unnecessary walking and make it impossible to couple machines; finally, too much labor is spent in moving material about. As the result of a realization of these facts, a new set of principles has been evolved which may be stated as follows:

1. When material is laid aside at the end of one operation, it should be placed in the position at which it may best be picked up for the next operation.
2. The distance that the operator must move to obtain or to lay aside material should be reduced to a minimum.
3. Time spent by a machine making a cut under power feed is idle time as far as the operator is concerned.

These three principles have a profound influence on plant layout. When applied, they usually result in layouts that look as chaotic to the uninformed observer as the original layouts. They are anything but inefficient, however, as can be recognized from the fact that there are no piles of material standing about, that there is very little material handling as a separate activity, and that one operator is often found to be operating more than one machine.

Types of Plant Layout.—Industrial plants are laid out in two different ways. First, all equipment for a given process may be grouped together; that is, all milling machines may be located in one part of the department, all welding in another, and all assembly work in still another. Process or horizontal grouping has several advantages. Because all operators doing a given class of work are located together, supervision is easier. New workers can observe experienced operators on similar jobs and can learn by observation. Material for repairs and servicing can be kept accessible in a near-by location. The appearance of a line-up of similar machines is pleasing. These reasons made process grouping popular throughout industry until fairly recent times.

The disadvantages of process grouping, however, became more and more apparent as detailed studies were made. It was seen that material handling would be greatly simplified if the machines and other equipment were placed in the order in which they were to be used in producing a given product. If, for example, a part was drilled, milled, painted, and assembled, the provision of a drill press, a milling machine, a paint booth, and an assembly bench lined up in order would permit the product to be manufactured with a minimum of handling. Hence, a different type of layout known as "product" or "vertical" grouping was developed.

Product grouping, of course, was always practiced in plants manufacturing a single standard product. The advantages were so obvious that equipment was arranged in the order in which it was used. In plants manufacturing a variety of products, however, the full possibilities of product grouping developed much later. Some of these plants had individual products which were manufactured in large quantities. In order to reduce costs, these products were separated from miscellaneous work, usually primarily to set up a separate costing center which might be assigned

a lower overhead or burden rate. When a single product was segregated and the equipment for producing it was set up in a special space, the equipment was arranged in conformance with the flow of material throughout the process or, in other words, product grouping was practiced.

The advantages gained were so striking that the possibilities of segregating other products were quickly sought. Product grouping replaced process grouping wherever possible.

On miscellaneous work, product grouping is impractical, and therefore process grouping must be used. Even in such cases, however, it is possible to make layouts that conform to the three principles mentioned above to a large extent. The lower half of Fig. 62 of Chap. XV shows the layout of a miscellaneous machining department in which process grouping is practiced. Because of the conveyer system, however, the layout operates effectively and in close conformity with the principles of good layout.

For example, the first principle states that, when material is laid aside at the end of one operation, it should be placed in the position at which it may best be picked up for the next operation. In the layout shown by the lower half of Fig. 62, the material is placed aside on the conveyer at the end of one operation. Through the agency of the conveyer system and the dispatcher, it is placed in a position convenient for the next operation.

The location of the lateral conveyers with respect to the machines and the machine operators follows the second principle as closely as is practical. Machines are placed close to the lateral conveyers so that the operators move a minimum distance to obtain and lay aside material.

The third principle covers machine coupling. Machine coupling is obtained in the layout by grouping several machines around a single operator and by supplying him with material for several jobs at one time, as described in the preceding chapter. The *X*'s on the lower layout, Fig. 62, represent the operators, and there are many more machines than operators.

It will be seen, therefore, that although there are two different types of plant layout, the principles of effective layout practice may be achieved with either type.

Collecting Layout Information.—It is a relatively simple matter to make an efficient layout if the principles to which it should

conform are clearly understood and if complete information is available regarding the product and the processes which it must undergo. If information is collected in the proper form, the layout may be said almost to make itself in a number of cases.

For layout purposes, the operation process chart is one of the most valuable tools available. In Chap. VII, the clearness with which the operation process chart shows the different steps of manufacture and suggests the form the layout should take has already been discussed.

In approaching a layout study, an operation process chart should first be constructed. If the layout is for a miscellaneous line of work, operation process charts should be constructed for representative jobs. In addition, information should be collected regarding the floor space available, expected yearly and monthly activity, and possibilities of greater production in the future. Samples of the product in various stages of completion will also be of assistance in visualizing the processes and the material-handling problem involved.

The time required to perform each operation should be carefully determined. If no time study data are available, time studies should be taken if the operations are being performed, or careful estimates should be prepared. This information is of primary importance, for the allowed time multiplied by the production desired per day will determine the number of work stations that must be provided for each operation.

When all information has been collected, it should be arranged for convenient use. A floor plan of the available manufacturing space is first laid out to scale on a table, drawing board, or sheet of stiff cardboard. The operation process chart should be placed where it can be studied easily; that is, it should be tacked to the wall in front of the layout table or placed in some other convenient position. The samples of the product should be lined up in the order of the process and placed where they may be glanced at from time to time.

Finally, all other data should be put in form for convenient reference. The manner in which this may be done is shown by Fig. 93. Present- and expected-activity data are first given. Then each operation is considered in order. The number of work stations required is computed and recorded, and any special information that may have a bearing on the process is noted.

The floor space occupied by each work station is ascertained and recorded.

Layout Templates.—During the course of a layout study, many different arrangements of equipment will be considered. Therefore, it is desirable to prepare templates (representing each work station or piece of equipment) which may be shifted about readily as different arrangements are considered.

Templates are made to the same scale as the floor plan. The scale ¼ inch = 1 foot is convenient for most layouts. Templates are commonly made from light cardboard or stiff drawing

LAYOUT DATA

INTERNAL COMBUSTION ENGINE CYLINDER HEAD — DWG. No. 128305-A
PRESENT PRODUCTION — 20 pcs. in 6 hrs.
ANTICIPATED PRODUCTION — To be handled by added shifts — DEPT. A-21

Operation	Allowed Time	Machine	No. Machines Required	Floor Space Each Machine	Machine Coupling Data: Man Time	Machine Coupling Data: Machine Time
Rough plane	0.58	3' Planer	2	5' x 12'	0.176	0.404
Rough mill - 1st. operation	0.41	#3 H.M.M.	1.37 See Markley about improved cutter	5' x 5'	0.066	0.344
Rough mill - 2nd. operation	0.225	#3 H.M.M.	1	5' x 5'	0.037	0.188
Anneal	8.0	Continuous annealing furnace	1	5' x 14'		
Sand blast	0.10	Pangborn sandblast	1	12' x 12'		
Finish plane	0.32	3' Planer	1	5' x 12'	0.097	0.223
Finish mill - 1st. operation	0.54	#3 H.M.M.	2	5' x 5'	0.072	0.468
Finish mill - 2nd. operation	0.27	#3 H.M.M.	1.23 Improve?	5' x 5'	0.041	0.229
Drill	0.302	5' R.D.P.	1	4' x 8'		
Inspect	0.05	Layout table	1	3' x 5'		

FIG. 93.—Typical data for layout study.

paper. They should represent the total floor space occupied by the equipment under extreme conditions. A milling machine, for example, should be represented with its table extended the maximum distance in each direction, and a screw machine should be shown with the maximum length of bar stock in place.

Sometimes, it may be desirable to show the space around the work station that is occupied by raw and finished material. If so, the space so occupied should be indicated by sectioning or color on the template. Different methods of handling material may be developed during the course of the layout study, and therefore a distinction should be made between space occupied

by equipment, which is not subject to change, and space occupied by material.

A layout representation should be as clear as possible, for a number of different individuals will examine it before it is finally approved. Small models of the equipment placed on a drawing or other representation of the available floor space as shown by Fig. 94 undoubtedly present the clearest understanding of the layout, but their preparation often consumes more time than is

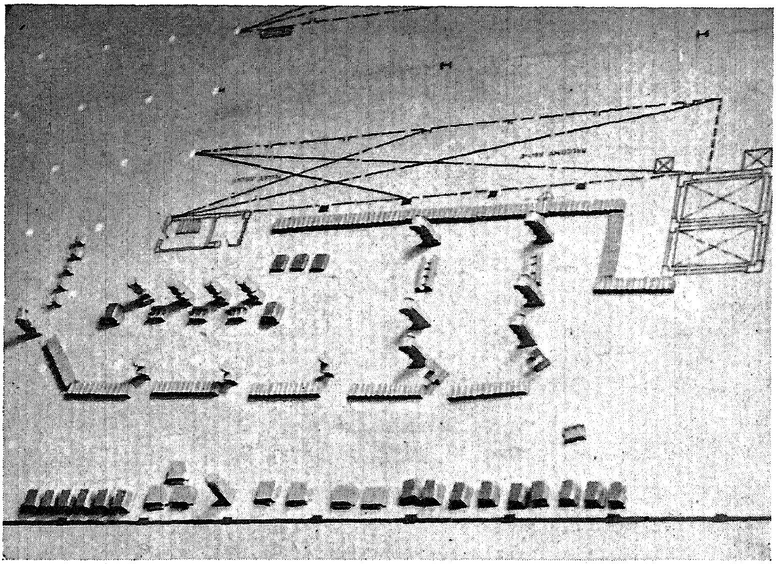


FIG. 94.—Layout study made with small models of equipment.

justified by the clearness gained. Photographs of equipment glued to the templates, as shown by Fig. 95, however, are comparatively easy to prepare and will add to the clearness of the layout. If photographs of a suitable size are not available, templates may be colored to distinguish among different types of equipment. If a layout when made has to be presented for approval to executives who are not particularly familiar with the work, the adoption or rejection of the proposed layout may depend upon the clearness with which it is presented.

Making the Layout.—The floor plan on which the layout is made may be a blank plan showing only the fixed features of the

floor space, such as columns, elevators, and washrooms; or if only a minor revision is contemplated, it may show the present location of all equipment. If the latter, the present flow of material can be indicated by lines drawn between machines and equipment to show the path followed by material.

The study of a layout is more than a one-man job. One man can collect information and samples and prepare the floor plan and templates. He can study the problem and make the best initial arrangement that he can conceive. In order to get the benefit of suggestions from every possible source, however, he

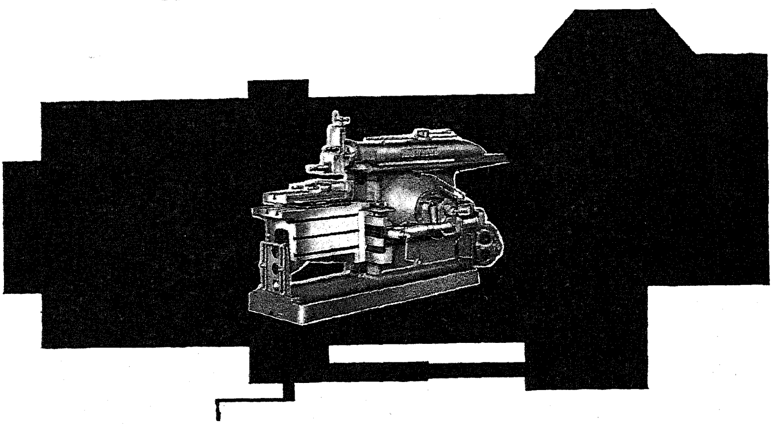


FIG. 95.—Layout template to scale on which has been pasted photograph of the machine it represents.

should then call in others and ask for criticism. The plant superintendent will view the problem from one angle, the foreman in charge of the work from another, and the operators who do the work from still another. Their comments and suggestions should be encouraged, for the resulting layout will be much improved.

When a number of individuals are commenting on a layout, many revisions will be suggested. The layout representation should be such, therefore, that it can be readily changed. At the outset, it may be inadvisable to fasten the templates in position in any way. If they are merely laid on the floor plan, they can be shifted about until a rough approximation of the desired arrangement is obtained. The templates must then be located carefully with all aisles, material-storage spaces, con-

veyers, and so on, represented to scale. At this point, it becomes desirable to fasten the templates down in position so that they will not move. Thumbtacks, map pins, brads, staples, or rubber cement may be used. If desired, tacks or map pins with different colored heads may be used to represent different classes of equipment.

A layout bristling with pins is not an easy object to handle. Therefore, rubber cement may be preferable for securing templates to the layout. A small dab of cement should be put on

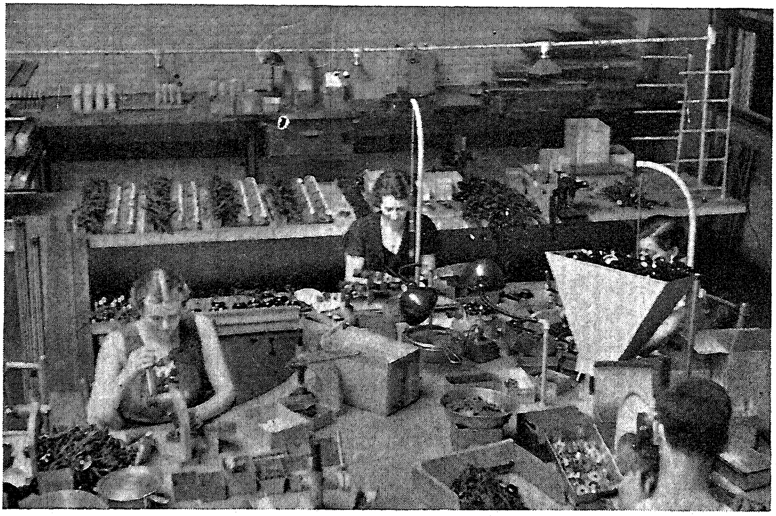


FIG. 96.—Portion of special bench designed for electric-clock motor assembly.

the back of the template and the template stuck in position. While the cement is wet, the template may be slid about as it is being brought into exact position. The cement hardens quickly and will hold the template securely. If, however, it is desired to remove the template, a slight pull will unstick it. The dried cement on the floor plan and on the template may be rubbed off with the finger, restoring them both to their original condition.

In working with templates, a two-dimensional representation is obtained, and there is a tendency to overlook the fact that the actual manufacturing space is three-dimensional. Hence, everything may be placed on the floor while overhead space is unoccupied. This point should be kept in mind while making layouts,

for material storage, conveyers, and so on, may often be placed above the floor level.

There is also a tendency to work with standard pieces of equipment and to try to make the process conform to the equipment rather than the equipment to the process. This is particularly true in connection with benches. Standard benches are used, and work is arranged on them as well as possible. Often, this involves extra travel of material and extra movement of oper-

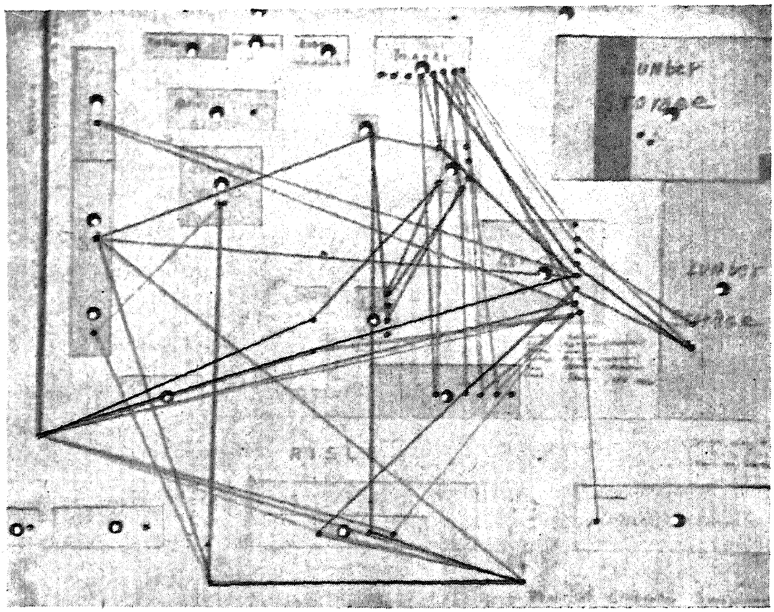


FIG. 97.—Layout study of woodworking shop during initial stages.

ators. Special benches are not costly, and they will often pay for themselves many times over. Figure 96 shows a portion of a special bench designed for a clock-motor assembly. The bench solved a difficult handling problem and permitted the work to flow so that when material is laid aside by one operator it is in convenient position for grasping by the next.

When an arrangement is arrived at that seems satisfactory, the flow of material should be indicated to ascertain if the shortest possible movements are called for. Since the layout is always subject to revision, material flow may best be indicated

by threads running from work station to work station. If tacks or pins are used to hold the templates in position, the thread may be run from tack to tack quite easily. If templates are secured by rubber cement, a dab of cement in the proper places will fasten the thread in position.

Figure 97 shows a typical layout representation at the initial stage of the study. Several different products are manufactured, and, hence, different-colored threads are used to show the flow of different products.

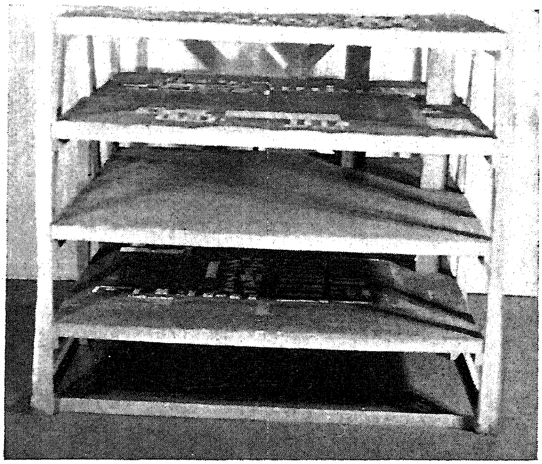


Fig. 98.—Floor layouts of multifloored building placed in rack to give three-dimensional representation. Wooden blocks between floors indicate elevators.

When manufacturing is done on different floors, layouts of each floor may be made separately. They may then be shown in their relation to one another by placing them one above the other in a holding rack, as shown by Fig. 98. A rack of this kind occupies considerable space, however; if this is an important consideration, it may be more desirable to attach the layout representation to a wall with hinges. When the layout is not in use, it hangs on the wall, occupying little space, as shown by Fig. 99. When it is needed, any or all floor representations can be swung up in a position for study, as shown by Fig. 100.

Testing the Layout.—When a given layout has been made in accordance with the foregoing methods and when it has been

reviewed by all who are in a position to offer constructive comment, the layout at this point represents the best arrangement that those who have worked on it can visualize. If the layout has been made for a single product or for a relatively few products,

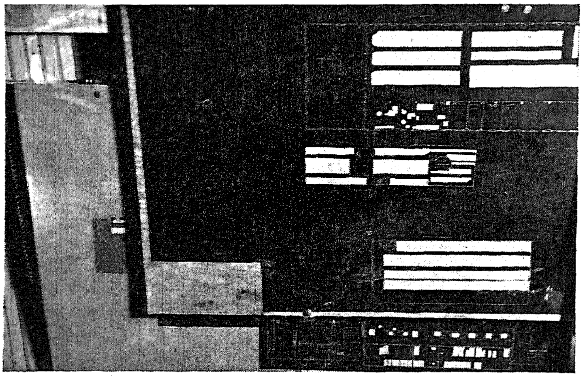


FIG. 99.—Three-dimensional layout representation folded back against wall when not in use.

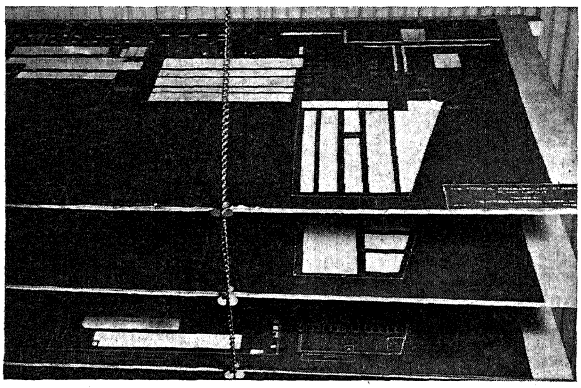


FIG. 100.—Three-dimensional layout representation in position for study.

it is probably safe to proceed with the physical arrangement of the equipment. If, however, the layout is designed for a variety of products, it is usually desirable to subject it to a more thorough test before beginning the physical moves.

The method of testing the flow of material by means of colored threads is useful at the initial stages of the layout, but if many

different products are involved, the layout eventually becomes covered with a maze of interweaving threads, and it is difficult to recognize the flow of individual items.

A clearer method of testing the flow of materials is to secure a number of copies of the layout reproduced on a small scale. The original layout may be photographed, and a number of 8½- by 11-inch prints obtained, or the layout may be redrawn to a smaller scale with a minimum amount of detail shown and a number of blueprints made. Each small-scale reproduction may then be used to show by means of lines the flow of a single item. Since only one item is shown at a time, any backtracking or excessive travel is clearly revealed.

If the machines used in the production of a given part are marked and the number of pieces per hour obtainable from each machine are shown, a very clear understanding of the way the product will move through the layout will be gained, and possible difficulties can be foreseen. For example, assume that a part is processed on two machines located side by side. If the production per hour is the same for each machine, the part will flow past this point without difficulty. If, however, the first machine produces at the rate of 600 pieces per hour and the second at the rate of 60 pieces per hour, parts are certain to pile up between the two machines.

With this fact clearly established, the necessary action can be taken to minimize manufacturing difficulties. The recognition of the bottleneck will suggest its elimination by improving the method for the second operation or by providing additional machines. If it cannot be eliminated, then sufficient floor space must be provided to hold the maximum amount of material that is likely to pile up ahead of the second machine.

Making the Physical Layout.—When all parts flowing through the layout have been tested individually and all undesirable conditions have been reduced to a minimum, the physical layout can be started with the certainty that it will function reasonably well. At the same time, no matter how carefully a layout may be made on paper, it is quite likely that it will not be perfect. In working with a small scale, distances that require a step or two to cover are so small that they may be overlooked. A two-dimensional representation does not portray clearly how the actual layout will look, and templates convey only a partial idea of the real nature

of the equipment. For these reasons, it is well to consider the paper layout as being only tentative and to check it carefully as the actual layout is made. At least one plant has established the rule that when new layouts are made or old layouts revised, no machine or piece of equipment is to be permanently fastened in position until a few pieces have been manufactured. Most equipment will operate for a while even if it is not firmly anchored, and by testing the layout in actual operation, opportunities for minor improvements are frequently discovered.

Preserving Layouts.—Changing conditions cause more or less frequent layout revisions. Therefore, the layout representations should be preserved for future use. Where changes in product are frequent, as for example, in the automobile industry, layout representations may be kept set up permanently so that they are always available for study. In more static industries, the layouts may be placed in a dustproof container and stored until wanted. A really clear layout representation takes some time to prepare, and it is usually more economical to store it than to make a new one the next time a revision is contemplated.

CHAPTER XX

OPERATION ANALYSIS—WORKING CONDITIONS AND METHOD

Work is done most effectively under good, comfortable working conditions. It is, therefore, part of the task of the analyst to seek to provide such conditions in so far as he is able. The various factors that have been considered up to this point have all been analyzed with the idea of providing the best tools, equipment, and work station possible. It requires human effort to operate the setup and do the prescribed task, however, and therefore, the conditions that affect human effort must also be considered thoroughly. It is difficult to obtain maximum production even with the finest tools made if the workplace is located in a hot, dark corner. Maximum skill cannot be attained if the attention of the operator is taken from his work by disagreeable surroundings.

Questions.—In his effort to improve working conditions, the analyst should consider the following points:

1. Is light ample and sufficient at all times?
2. Are the eyes of the operator protected from glare and from reflections from bright surfaces?
3. Is lighting uniform over the working area?
4. Has lighting been checked by an illumination expert?
5. Is proper temperature for maximum comfort provided at all times?
6. Is plant unduly cold in winter, particularly on Monday mornings?
7. Is plant unduly warm in summer?
8. Would installation of air-conditioning equipment be justified?
9. Can fans be used to remove heat from solder pots, furnaces, or other heat-producing equipment?
10. Could an air curtain be provided to protect operator from intense heat?
11. Is ventilation good?

12. Are drafts eliminated?
13. Can fumes, smoke, and dust be removed by an exhaust system?
14. Is floor warm and not damp?
15. If concrete floors are used, can mats or platforms be provided to make standing more comfortable?
16. Are drinking fountains located near by?
17. Is water cool, and is there an adequate supply?
18. Are washrooms conveniently located?
19. Are facilities adequate and kept properly clean?
20. Are lockers provided for coats, hats, and personal belongings?
21. Have safety factors received due consideration?
22. Is floor safe, smooth but not slippery?
23. Is wooden equipment, such as work benches, in good condition and not splintery?
24. Are tools and moving drives and parts properly guarded?
25. Is there any way operator can perform operation without using safety devices or guards?
26. Has operator been taught safe working practices?
27. Is clothing of operator proper from safety standpoint?
28. Are workplace and surrounding space kept clear at all times?
29. Do plant, benches, or machines need paint?
30. Does plant present neat, orderly appearance at all times?

The improvements that can be made in working conditions are many, and the more progressive industries are constantly making them. The improvements required in any given case depend, of course, upon the conditions already in effect. The list of questions, however, suggests the kind of changes that should be considered. Many of the points need no elaboration, but a brief discussion of a few of the principal factors may prove of value.

Light, Heat, and Ventilation.—Light, heat, and ventilation are matters that may properly be left to the illumination and heating engineers. Special training and background are required which the methods analyst cannot be expected to have. The analyst can, however, tell by personal observation when these conditions are bad, and he can point out the effect that they have on production. Accurate work, for instance, cannot be done in the

dark, and if the analyst encounters improper lighting conditions, he should take steps to have them corrected. In many communities, the utility companies provide experts who will survey lighting conditions and make recommendations without cost. Advantage should be taken of this service even where lighting to the untrained observer appears fairly good. Eyestrain is a serious matter and can and should be eliminated.

Light and heat cost money. At the same time, the difference in cost between good light and poor light or sufficient heat and

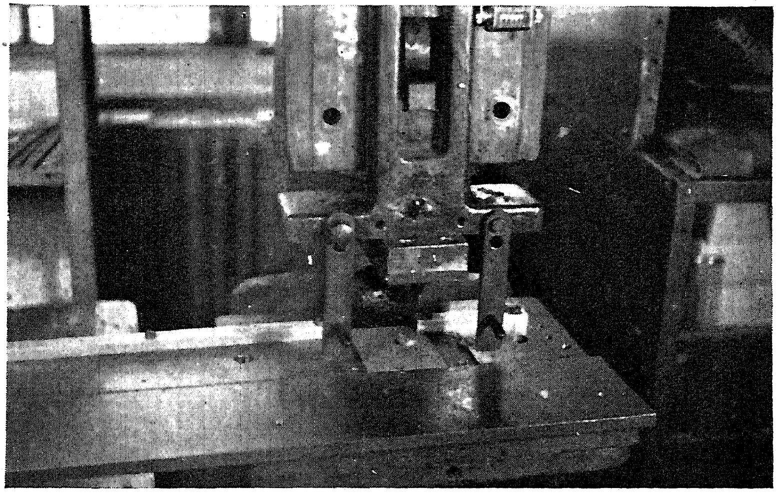


FIG. 101.—Kick press equipped with safety device.

insufficient heat is not great. It has been shown conclusively that good working conditions pay. Although it is often difficult to measure directly and immediately the saving brought about by the installation of a new lighting or heating system, it is a good policy to recommend their provision wherever the present systems are found to be inadequate. Throughout industry, it is found that the plants which provide the best working conditions are those which are leaders in their field. This alone would indicate that the provision of good conditions is a profitable investment.

Safety.—Safety engineering and methods engineering are closely related, although the fact is not always recognized. The methods engineer is interested in labor effectiveness. In order to

work effectively, the operator must be able to concentrate upon the work at hand. If an accident hazard exists, however, he must divide his attention between doing the job and keeping out of danger. Therefore, the methods engineer is interested in safety and the elimination of accident hazards.

As the result of his detailed study, the analyst gains a thorough knowledge of the operation, the equipment, and the working methods. He is, therefore, in an excellent position to discover accident hazards and to make suggestions for their elimination. He studies every move made by the operator, and hence he discovers the moves that carry parts of his body into a danger

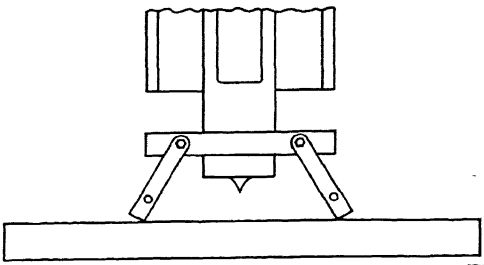


FIG. 102.—Position of safety device if treadle of kick press, Fig. 101, is not completely released.

zone. He can then either eliminate the moves by changing the motion sequence or take steps to have the danger zone guarded.

Figure 101 shows a kick press equipped with a safety device in the form of two bars hanging from the head of the machine. When an analysis was begun of the work performed by this machine, the analyst was informed that the device was foolproof, that it was the best safety device in the department, and that no change should be made to it. The analyst, however, considered the operation of this safety device along with all the other factors of the job. In order to operate the kick press, the operator had to place the material in position, grasp the two bars, and swing them to one side. He then stepped on the treadle of the machine and performed the operation.

The operation appeared clumsy and inefficient to the analyst. Because the material could not be held in place by the operator, it tended to slide out of position. Clips were provided to hold it down, but to use them required so much time that the operator

preferred not to do so. As a result, the material did slip out of position occasionally, and scrap was produced. The movements necessary to operate the bars carried the hands of the operator out of the danger zone, but they were fatiguing and time-consuming. A further investigation of the "foolproof" device showed that it could be circumvented very easily. If after making a stroke with the press, the operator did not allow the treadle fully to return to the off position, the bars rested in the position shown by Fig. 102. There was plenty of room to draw material through the die. When the treadle was depressed again, the bars slid to the position shown by Fig. 103, untouched by the operator. A

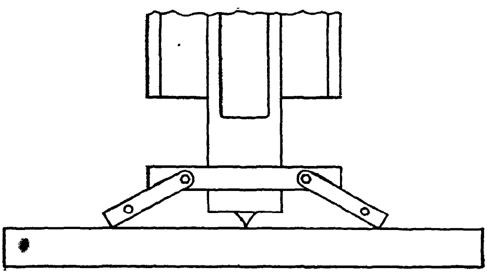


FIG. 103.—Position of safety device if treadle of kick press is depressed starting from position shown in Fig. 102.

small and inconspicuous block of wood affixed to the treadle of the machine would prevent it from returning to its off position, and hence the operation could be done easily without using the safety device.

In this particular case, there was no evidence that the operator was circumventing the safety device. The possibility was there, however, and since general experience indicates that safety devices will be circumvented by the operator from time to time, particularly if their use consumes much time, the condition was undesirable. The safety engineer was quick to realize this when the condition was brought to his attention. He and the analyst then proceeded to devise the guard shown by Fig. 104. This guard really is foolproof. The operator cannot get his fingers under the die in any way, but he has complete control of the operation at all times. As a result, the operation is safer and much faster than it was before.

Other Conditions.—Space is provided on the analysis sheet under item 8 for comments about any factors that affect the operation that have not previously been considered. The following list of questions will indicate the kind of items that should be considered at this point:

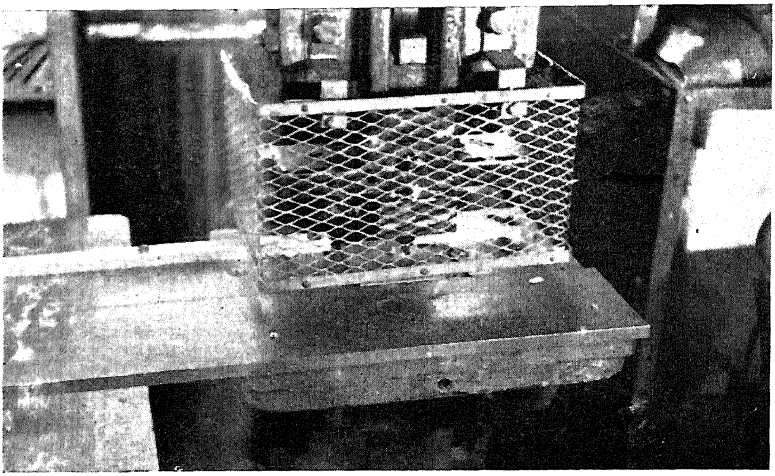


FIG. 104.—Kick press equipped with superior type of guard.

1. How is the amount of finished material counted?
2. Is there a definite check between pieces completed and pieces paid for?
3. Can automatic counters be used?
4. Is pay-roll procedure understandable?
5. Is the design of the part suitable to good manufacturing practices?
6. What clerical work is required from the operator to fill out time cards, material requisitions, and the like?
7. Can this work be delegated to a clerk?
8. What sort of delay is likely to be encountered by the operator, and how can it be avoided?
9. How is defective work handled?
10. Should operator grind his own tools, or should this be done in toolroom?
11. Should order department be requested to place fewer orders for larger quantities?

12. What is the economic lot size for the job being analyzed?
13. Are adequate performance records maintained?
14. Are new men properly introduced to their surroundings, and are sufficient instructions given them?
15. Are failures to meet standard performance requirements investigated?
16. Are suggestions from workers encouraged?
17. Do workers understand the incentive plan under which they work?
18. Is a real interest developed in the workers in the product on which they are working?
19. Are working hours suitable for efficient operation?
20. Is the utilization of costly supply materials checked?

It will be seen from the general nature of the questions listed above that the methods engineer recognizes his responsibility

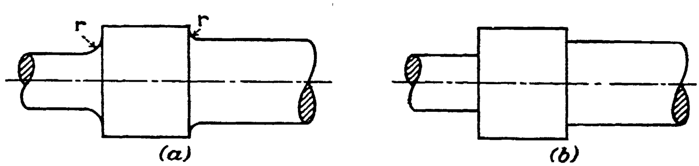


FIG. 105.—Fillets are better from a machining standpoint on lathe work than square corners.

toward everything connected with the job he is analyzing. It will not satisfy him to say that the designs are made by the engineering department or that the shop routine is set up by the management. He realizes that his own intimate knowledge of shop methods and conditions gives him an advantage which many other members of the organization do not possess, and he therefore feels it his duty to question all phases of manufacture in the hope of revealing possibilities for improvement.

For example, a designer who is making a drawing of a steel shaft, having in its length several different diameters, knows how to lay out the shaft, taking into consideration strength, size, and suitability of purpose. He probably knows in a general way that the shaft will be turned on a lathe and that at the junction of two sections of different diameters it is better from the standpoint of ease of machining to call for a fillet with radius r as in (a), Fig. 105, rather than to specify a squared-out corner as shown in (b)

of the same figure. What he may not realize, however, is that for reasons of manufacturing economy, the fillet is machined with a specially ground tool, known as a "radius tool," which is the exact size of the radius to be turned. Therefore, if there are several fillets to be turned on the same shaft, he may call for, say one 1/4-inch radius, two 3/8-inch radii, and one 1/2-inch radius, being governed largely by the difference in the diameters of the adjacent sections.

If this incorrect and unnecessary feature of design is allowed to pass unchallenged, it means that three radius tools must be used instead of one. When the shaft is turned on an engine lathe, time for two extra "change tool" operations must be allowed. This is unnecessary and wasteful, and the design should be changed.

From the nature of the many examples of operation improvements that have been given throughout this book, it will be seen that if the analyst is to do his work so as to bring about maximum manufacturing economy, he must concern himself with every detail connected with every job he studies. Common sense, of course, must be used in interpreting this statement. In practical work, it means that the analyst should consider, at least briefly, every detail that is likely to affect operation time.

Method.—All analysis work is done for the purpose of improving the method by which the operation is done. The various factors that affect method directly or indirectly are considered in detail, and improvements are made wherever possible. As a result, many economies are made that eliminate motions and reduce costs.

Before the study can be considered complete, however, the motions that remain and that appear to be necessary must themselves be studied in considerable detail. It is not enough to say that a part is to be obtained by picking it out of the gravity delivery chute. The location of the end of the chute should be such that the hand can move between it and the point where the material is worked upon with the shortest and lowest class motion. The height of the chute should be such that the transport motions can be made without a change of direction. The motions used for grasping must be worked out so that the fewest possible are employed. If two parts are required, it must be decided whether they are to be grasped and transported together or separately. The best position of the hand and of the material in the hand must

be determined so that no time is lost in positioning the material at the place of work.

In short, every motion must be analyzed in detail for the purpose of shortening it and making it as effective as possible. This, a secondary form of analysis, is known as motion study. Motion study is itself a detailed procedure which will require as lengthy a discussion as the subject of operation analysis. Therefore, it will merely be mentioned here that motion study is the next logical step in the methods study after operation analysis.

CHAPTER XXI

OPERATION-ANALYSIS CHECK SHEET

The analysis sheet serves as a guide in analyzing an operation. It is, however, merely in outline form, and detailed, searching investigation is carried on in the mind of the analyst by asking the type of questions listed in Chaps. XI to XVII and Chapter XX.

The danger in this procedure lies in the fact that the analyst may make his analyses too hurriedly and may forget to ask himself one or more questions that if they had been asked might have suggested a new line of thought and developed improvements. To overcome this, when operations of major importance are being studied, the analysis check sheet, reproduced on the following pages, may be used. The analysis check sheet is an expansion of the analysis sheet. It lists all the questions that should be asked on each item on the analysis sheet and requires a definite answer to each question.

An analysis conducted with the aid of the analysis check sheet is certain to be much more thorough than when the analysis sheet only is used. Its very thoroughness, however, is likely to be a deterring factor in using it, for it requires considerable time and effort to fill it out. For this reason, its use is recommended only when the importance of the operation is sufficient to justify a really thorough study.

Using the Analysis Check Sheet.—If it is decided that it is justifiable from an economic standpoint to make out an analysis check sheet, the filling out should be complete. No part of it should be slighted, for if a hurried consideration of the major features of the job is all that is desired, the analysis check sheet should not be used at all.

The first page provides for the identification of the analysis itself. Then on the next page, the operation is identified and described in detail. At this point, before any time is spent on detailed analysis, the activity and the cost of the job are considered. First, the yearly labor cost per 0.0001 hour is established. This offers a quick means of testing the practicability

of any suggested improvement. If the expected saving in decimal hours multiplied by the yearly labor cost per 0.0001 hour does not exceed the cost of adopting the suggestion, it usually will not pay to make the improvement.

The expected life of the job and the manual-labor content are also considered at this point in order to check the type of study which should be made in accordance with the method described in Chap. V. Unless a type A study is strongly indicated, the analysis check sheet ordinarily would not be used.

After the operation has been described and the justification for using the analysis check sheet has been established, the nine points of primary analysis are considered in turn. The purpose of the operation is first described in detail. Then the questions that should be asked in connection with this point are taken up, one at a time. After each question has been considered carefully, the answer decided upon is recorded in detail. When all questions have been considered, the final conclusions and any remarks that might be of value at some time in the future are recorded.

Similarly, all other points are considered. The detail is great, but the results on jobs of major importance are sufficiently superior to the briefer forms of analysis to justify the work involved.

The Analysis Check Sheet and Industrial Training.—Most progressive industrial organizations conduct training courses for their supervisors and key men. One of the subjects of great interest to those receiving the training is a discussion of practical ways of improving factory-operating methods, and the analysis check sheet offers an excellent way of developing a series of discussions on this subject.

In this connection, the following suggestions may prove helpful. Each member of the training group should be given a copy of the analysis check sheet, and its use and purpose should be briefly described. Then an operation from the plant should be selected for analysis. One step of analysis should be taken up at a time. The discussion leader should discuss the first step in general terms, keeping away from the case operation but bringing up examples from other operations or other industries. The group members should then be required to fill in the analysis check sheet for the step just discussed, analyzing, of course, the selected case operation. This part of the work may be assigned to be done between meetings.

ANALYSIS CHECK SHEET

Part ______________________________

Operation ______________________________

Work Station ______________________________

Analysis Begun ______________

Analysis Completed ______________ Analyzed by ______________

Methods Engineering Council
Form No. 125

OPERATION IDENTIFICATION

Part Description ______________________________

____

____

Operation ______________________________

____

____

Operators ______________________ Drawing ______________

______________________ Department ______________

____

Remarks ______________________________

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Cost and Activity Data

Yearly activity of job ____________

Labor rate per hour ____________

Yearly labor cost per 0.0001 hour*

____

Expected life of job ____________

Manual-labor content ____________

Type of methods study ____________

* Activity × Labor Rate × 0.0001

Sketch or Photograph of Part

Description of Present Method

DETAILS OF OPERATION ANALYSIS

1. Purpose of Operation (Describe) ______________________

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____

Is the result accomplished by the operation necessary? If so, what makes it necessary? Was the operation established to correct a difficulty experienced in the final assembly? If so, did it really correct it? Is the operation necessary because of the improper performance of a previous operation? Was the operation established to correct a condition that has since been corrected otherwise? If the operation is done to improve appearance, is the added cost justified by added salability? Can the purpose of the operation be accomplished better in any other way? Can the supplier of the material perform the operation more economically?	

Remarks and Conclusions

2. Operations Performed on Part (List or Operation Process Chart)

Can the operation being analyzed be eliminated by changing the procedure or the operations?	
Can it be combined with another operation?	
Can it be subdivided and the various parts added to other operations?	
Can part of the operation be performed more effectively as a separate operation?	
Can the operation being analyzed be performed during the idle period of another operation?	
Is the sequence of operations the best possible?	
Would changing the sequence affect this operation in any way?	
Should this operation be done in another department to save cost or handling?	

If several or all operations including the one being analyzed were performed under the group system of wage payment, would advantages accrue? Should a more complete study of operations be made by means of an operation process chart?	

Remarks and Conclusions

3. Inspection Requirements (Describe) ______________________________

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By whom were the inspection requirements described above established?	
What are the requirements of the preceding operation?	
What are the requirements of the following operation?	
Will changing the requirements of a previous operation make this operation easier to perform?	
Will changing the requirements of this operation make a subsequent operation easier to perform?	
Are tolerance, allowance, finish, and other requirements necessary?	
Are they suitable for the purpose the part has to play in the finished product?	
Can the requirements be raised to improve quality without increasing cost?	
Will lowering the requirements materially reduce costs?	
Can the quality of the finished product be improved in any way even beyond present requirements?	

Remarks and Conclusions

4. Material (Describe Specifically) ____________________

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Does the material specified appear suitable for the purpose for which it is to be used?	
Could a less expensive material be substituted that would function as well?	
Could a lighter gage material be used?	
Is the material furnished in suitable condition for use?	
Could the supplier perform additional work upon the material that would make it better suited for its use?	
Is the size of the material the most economical?	
If bar stock or tubing, is the material straight?	
If a casting or forging, is the excess stock sufficient for machining purposes but not excessive?	
Can the machinability of the material be improved by heat-treatment or in other ways?	
Do castings have hard spots or burned-in core sand which should be eliminated?	
Are castings properly cleaned and have all fins, gate ends, and riser bases been removed?	
Is material sufficiently clean and free from rust?	
If dies are coated with a preserving compound, how does this compound affect them?	
Is material ordered in amounts and sizes that permit its utilization with a minimum amount of waste, scrap, or short ends?	
Is material uniform and reasonably free from flaws and defects?	
Is material utilized to the best advantage during processing?	
Where yield from a given amount of material depends upon ability of the operator, is any record of yield kept?	

Is miscellaneous material used for assembly, such as nails, screws, wire, solder, rivets, paste, and washers, suitable? Are the indirect or supply materials such as cutting oil, molding sand, or lubricants best suited to the job? Are materials used in connection with the process, such as gas, fuel, oil, coal, coke, compressed air, water, electricity, acids, and paints, suitable; and is their use controlled and economical?	

Remarks and Conclusions

5. Material-handling Methods (Describe) ______________________

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Is the time consumed in bringing the material to the work station and in removing it large in proportion to the time required to handle it at the work station?	
If not, should material handling be done by operators to provide rest through change of occupation?	
Should hand trucks be used?	
Should electric trucks be used?	
Should special racks or trays be designed to permit handling the material easily and without damage?	
Where should incoming and outgoing material be located with respect to the work station?	
Is a conveyer justified?	
If so, what type would best be suited to the job?	
Can the work stations for the successive steps of the process be moved close together and material handling accomplished by means of gravity chutes?	
Can the operation be done on the conveyer?	
Can a progressive assembly line be set up?	
Can material be pushed from operator to operator along the surface of the bench?	
Can material be dispatched from a central point by means of a conveyer?	
Can material be brought to a central inspection point by conveyer?	
Can weighing scales be incorporated to advantage in the conveyer?	
Is the size of the material container suitable for the amount of material transported?	
Can container be designed to make material more accessible?	

Can container be placed at work station without removing material?	
Can electric or air hoist or other lifting device be used to advantage at work station?	
If overhead traveling crane is used, is service rendered prompt and adequate?	
Can a pneumatic tube system be used to convey small parts or orders and paper work?	
Will signals such as lights or bells notifying move men that material is ready for transportation improve service?	
Can a tractor-trailer train running on a definite schedule be used?	
Can an industrial railway running on tracks be used?	
Can a tractor-trailer or industrial railway system be replaced by a conveyer?	
If helper is needed to handle large parts at work station, can a mechanical handling means be substituted?	
Can gravity be utilized by starting first operation of a series at higher than floor level?	
Can scrap or waste material be handled more effectively?	
Can departmental layout be changed to improve material-handling situation?	
Should the material-handling problem in general receive more intensive study in the immediate future?	

Remarks and Conclusions

6. Setup, Tools, and Workplace Layout (Sketch)

How is the job assigned to the operator?

Is the procedure such that the operator is ever without a job to do?

How are instructions imparted to the operator?

How is material secured?

How are drawings and tools secured?

How are the times at which the job is started and finished checked?

What possibilities for delays occur at drawing-, tool-, or storeroom or time clerk's office?

If operator makes his own setup, would economies be gained by providing special setup men?

Could a supply boy get tools, drawings, and material?

Is the layout of the operator's locker or tool drawer orderly so that no time is lost searching for tools or equipment?

Are the tools that the operator uses in making his setup adequate?

Is the machine set up properly?

Is the machine adjusted for proper feeds and speeds?

Is machine in repair and are belts tight and not slipping?

If vises, jigs, or fixtures are used, are they securely clamped to the machine?

Is the order in which the elements of the operation are performed correct?

Does the workplace layout conform to the principles that govern effective workplace layouts?

Is material properly positioned?

Are tools pre-positioned?

Are the first few pieces produced checked for correctness by anyone other than the operator?

What must be done to complete operation and put away all equipment used?

Can trip to return tools to toolroom be combined with trip to get tools for next job?

How thoroughly should workplace be cleaned?

What disposal is made of scrap, short ends, or defective parts?

If operation is performed continuously, are preliminary operations of a preparatory nature necessary the first thing in the morning?

Are adjustments to equipment on a continuous operation made by the operator?

How is material supply replenished?

If a number of miscellaneous jobs are done, can similar jobs be grouped to eliminate certain setup elements?	
How are partial setups handled?	
Is the operator responsible for protecting workplace overnight by covering it or locking up valuable materials?	
Is the machine tool best suited to the performance of the operation of all that are available?	
Would the purchase of a better machine be justified?	
Can the work be held in the machine by other means to better advantage?	
Should a vise be used?	
Should a jig be used?	
Should clamps be used?	
Is the jig design good from a motion economy standpoint?	
Can the part be inserted and removed quickly from the jig?	
Would quick-acting cam-actuated tightening mechanisms be desirable on vise, jig, or clamps?	
Can ejectors for automatically removing part when vise or jig is opened be installed?	
Is chuck of best type for the purpose?	
Would special jaws be better?	
Should a multiple fixture be provided?	
Should duplicate holding means be provided so that one may be loaded while machine is making a cut on a part held in the other?	
Are cutters proper?	
Should high-speed steel or cemented carbide be used?	
Are tools properly ground?	
Is the necessary accuracy readily obtainable with tool and fixture equipment available?	
Are hand tools pre-positioned?	
Are hand tools best suited to purpose?	
Will ratchet, spiral, or power-driven tools save time?	
Are all operators provided with the same tools?	
Can a special tool be made to improve the operation?	
If accurate work is necessary, are proper gages or other measuring instruments provided?	
Are gages or other measuring instruments checked for accuracy from time to time?	

Remarks and Conclusions

7. Consider and Record Conclusions on Following Possibilities for Improvement
a. Install gravity delivery chutes
b. Use drop delivery
c. Compare methods if more than one operator is working on job
d. Provide correct chair for operator
e. Improve jigs or fixtures by providing ejectors, quick-acting clamps, etc.

f. Use foot-operated mechanisms
g. Arrange for two-handed operation
h. Arrange tools and parts within normal working area
i. Change layout to eliminate backtracking and to permit coupling of machines
j. Utilize all improvements developed for other jobs

8. Working Conditions (Describe) ________________________________

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Is light ample and sufficient at all times?

Are the eyes of the operator protected from glare and from reflections from bright surfaces?

Is lighting uniform over the working area?

Has lighting been checked by illumination expert?

Is proper temperature for maximum comfort provided at all times?

Is plant unduly cold in winter, particularly on Monday mornings?

Is plant unduly hot in summer?

Would installation of air-conditioning equipment be justified?

Can fans be used to remove heat from solder pots, furnaces, or other heat-producing equipment?

Could an air curtain be provided to protect operator from intense heat?

Is ventilation good?

Are drafts eliminated?

Can fumes, smoke, and dust be removed by an exhaust system?

Is floor warm and not damp?

If concrete floors are used, can mats or platforms be provided to make standing more comfortable?

Are drinking fountains located near-by?

Is water cool, and is there an adequate supply?

Are washrooms conveniently located?

Are facilities adequate and kept properly clean?

Are lockers provided for coats, hats, and personal belongings?

Have safety factors received due consideration?

Is floor safe, smooth but not slippery?

Is wooden equipment such as work benches in good condition and not splintery?

Are tools and moving drives and parts properly guarded?

Is there any way operator can perform operation without using safety devices or guards?

Has operator been taught safe working practices?

Is clothing of operator proper from safety standpoint?

Are workplace and surrounding space kept clear at all times?

Do plant, benches, or machines need paint?

Does plant present neat, orderly appearance at all times?

How is the amount of finished material counted?

Is there a definite check between pieces completed and pieces paid for?

Can automatic counters be used?

Is pay-roll procedure understandable?

Is the design of the part suitable for good manufacturing practices?

What clerical work is required from the operator in filling out time cards, material requisitions, and the like? Can this work be delegated to a clerk? What sorts of delay are likely to be encountered by the operator, and how can they be avoided? How is defective work handled? Should operator grind his own tools, or should this be done in toolroom? Should order department be requested to place fewer orders for larger quantities? What is the economic lot size for the job being analyzed? Are adequate performance records maintained? Are new men properly introduced to their surroundings, and are sufficient instructions given them? Are failures to meet standard performance requirements investigated? Are suggestions from workers encouraged? Do workers understand the incentive plan under which they work? Is a real interest developed in the workers in the product on which they are working? Are working hours suitable for efficient operation? Is the utilization of costly supply materials checked?	

Remarks and conclusions

9. Method (Describe all improvements made and savings that resulted. List additional improvements that might be made if activity increases or if other conditions change)

Summary of Results

Cost of Analysis ________________ Yearly Saving ________________

Cost of Changes ________________ Other Advantages ________________

____

Signed ________________

At the next meeting, a very interesting discussion may be built around the results of the group's analysis. If the discussion leader is able to develop generalizations from specific points, he can widen the field of the discussion to cover all the plant's operations. One idea will lead to another, and the meetings will prove exceptionally interesting.

As a by-product of this type of training, a definite improvement in the job being analyzed may be expected. If the operation involves a fairly large yearly labor cost, the savings resulting from suggestions made by the discussion group may easily offset the cost of the training. In fact, all industrial training on the subject of methods engineering is usually self-supporting for this same reason.

CHAPTER XXII

PROGRESS PROCESS CHARTS

When a job is studied in great detail operation by operation, a number of suggestions for improvement will almost inevitably be made. Some of these will be adopted and put into effect at once. Others will be held up pending the decision of another department or supervisor. Still others will require experimentation to determine their feasibility, or several suggestions affecting the same point will have to be tried out to see which is the best.

As a result of this, the exact status of a study at any particular moment is often uncertain. This is particularly true if the study is being made by a group. Because a number of different viewpoints are brought to bear upon the job, greater accomplishments are likely to be made by a group than an individual. At the same time, because several people are involved, it is more difficult to keep their efforts pointed in the same general direction and to give them the same understanding of the problem and its solution. In order to avoid working at cross-purposes, the group should pause from time to time to review what has already been accomplished, what is pending, and what remains to be done.

The progress process chart is a device that is designed for this purpose. It shows clearly and in a related manner the status of the job and of each operation of the job at the moment the chart was drawn up.

Typical Progress Process Charts.—The progress process chart, or progress chart, is commonly prepared in two different forms. It may be drawn in the same manner as the operation process chart, or it may be a mere tabulation.

Figure 31 in Chap. VII showed the operation process chart that was prepared at the beginning of a study of the manufacture of an electric-clock motor and drum. This study was begun by an experienced methods engineer; but as it progressed, the various members of the supervisory force became intensely interested in it and cooperated so whole-heartedly that the study soon assumed

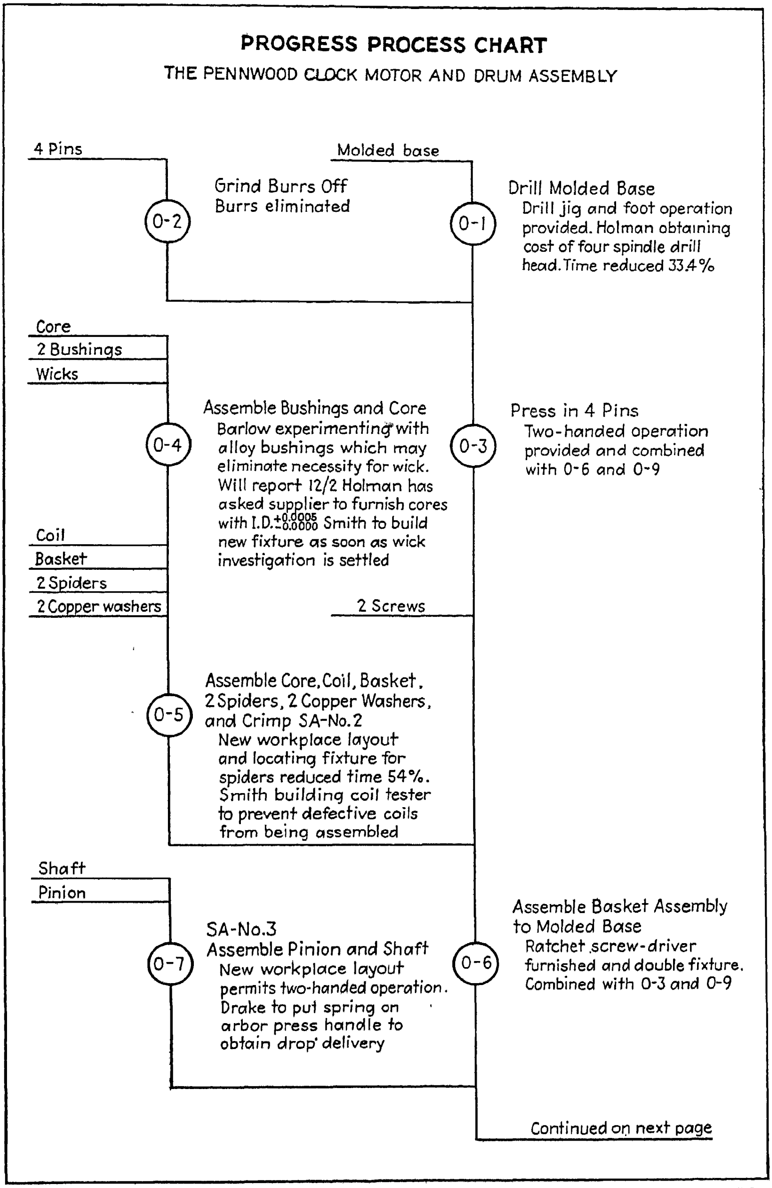
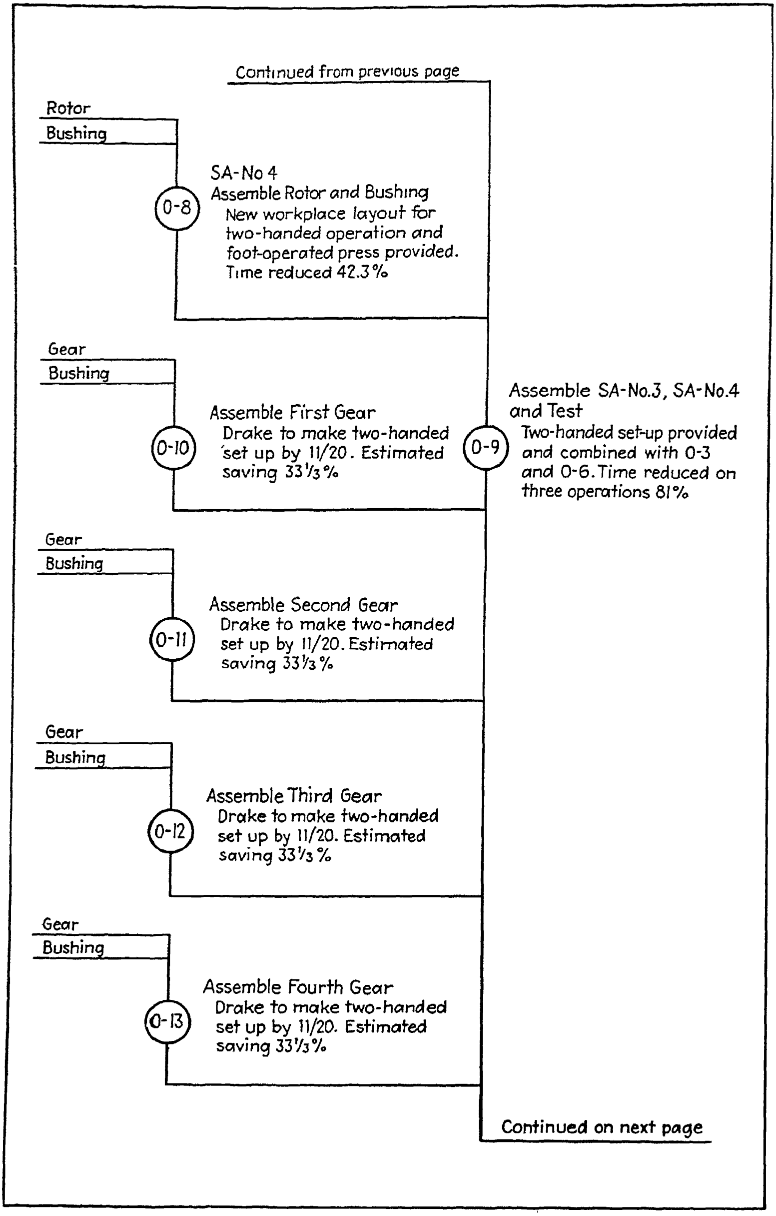
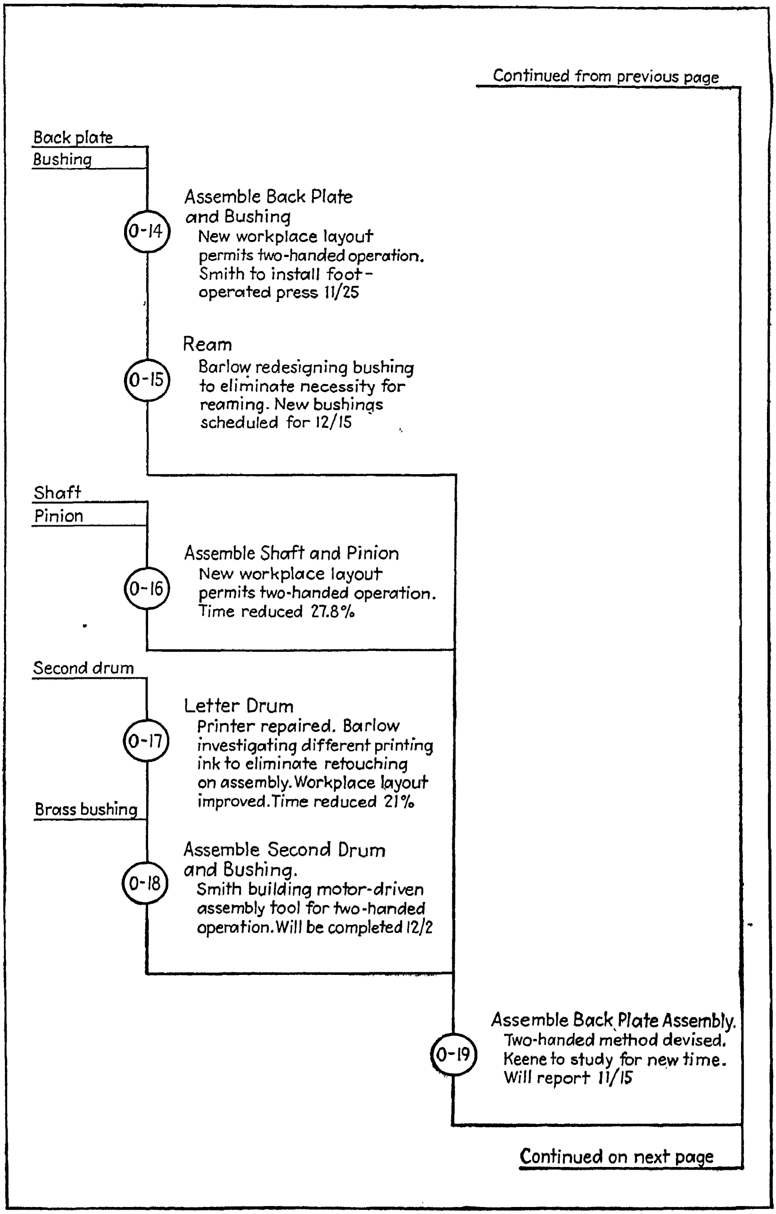


FIG. 106.—Progress process chart for electric-clock motor and drum assembly.


Continued from previous page
Rotor
Bushing
0-8
SA-No 4
Assemble Rotor and Bushing
New workplace layout for two-handed operation and foot-operated press provided. Time reduced 42.3%
Gear
Bushing
0-10
Assemble First Gear
Drake to make two-handed set up by 11/20. Estimated saving 33⅓%
0-9
Assemble SA-No.3, SA-No.4 and Test
Two-handed set-up provided and combined with 0-3 and 0-6. Time reduced on three operations 81%
Gear
Bushing
0-11
Assemble Second Gear
Drake to make two-handed set up by 11/20. Estimated saving 33⅓%
Gear
Bushing
0-12
Assemble Third Gear
Drake to make two-handed set up by 11/20. Estimated saving 33⅓%
Gear
Bushing
0-13
Assemble Fourth Gear
Drake to make two-handed set up by 11/20. Estimated saving 33⅓%
Continued on next page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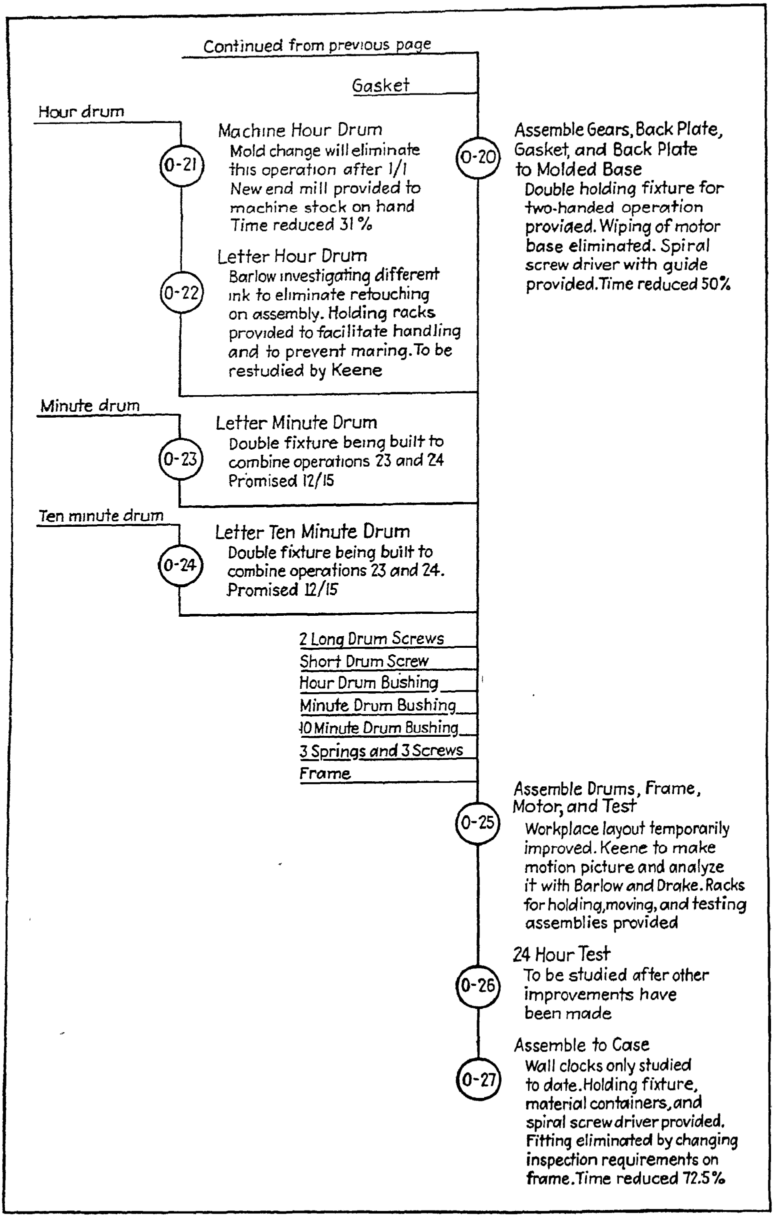
Back plate
Bushing
0-14
Assemble Back Plate and Bushing
New workplace layout permits two-handed operation. Smith to install foot-operated press 11/25
0-15
Ream
Barlow redesigning bushing to eliminate necessity for reaming. New bushings scheduled for 12/15
Shaft
Pinion
0-16
Assemble Shaft and Pinion
New workplace layout permits two-handed operation. Time reduced 27.8%
Second drum
0-17
Letter Drum
Printer repaired. Barlow investigating different printing ink to eliminate retouching on assembly. Workplace layout improved. Time reduced 21%
Brass bushing
0-18
Assemble Second Drum and Bushing.
Smith building motor-driven assembly tool for two-handed operation. Will be completed 12/2
0-19
Assemble Back Plate Assembly.
Two-handed method devised. Keene to study for new time. Will report 11/15
Continued on next page


Continued from previous page
Gasket
Hour drum
Machine Hour Drum
Mold change will eliminate this operation after 1/1 New end mill provided to machine stock on hand Time reduced 31 %
0-21
Letter Hour Drum
Barlow investigating different ink to eliminate retouching on assembly. Holding racks provided to facilitate handling and to prevent maring. To be restudied by Keene
0-22
0-20
Assemble Gears, Back Plate, Gasket, and Back Plate to Molded Base
Double holding fixture for two-handed operation provided. Wiping of motor base eliminated. Spiral screw driver with guide provided. Time reduced 50%
Minute drum
Letter Minute Drum
Double fixture being built to combine operations 23 and 24 Promised 12/15
0-23
Ten minute drum
Letter Ten Minute Drum
Double fixture being built to combine operations 23 and 24. Promised 12/15
0-24
2 Long Drum Screws
Short Drum Screw
Hour Drum Bushing
Minute Drum Bushing
10 Minute Drum Bushing
3 Springs and 3 Screws
Frame
Assemble Drums, Frame, Motor, and Test
Workplace layout temporarily improved. Keene to make motion picture and analyze it with Barlow and Drake. Racks for holding, moving, and testing assemblies provided
0-25
24 Hour Test
To be studied after other improvements have been made
0-26
Assemble to Case
Wall clocks only studied to date. Holding fixture, material containers, and spiral screw driver provided. Fitting eliminated by changing inspection requirements on frame. Time reduced 72.5%
0-27

the aspects of a group study. Before long, a number of suggestions for improvement were made, some of which have been described from time to time in the foregoing pages. About a month after the study was begun, so many changes and suggestions for changes had been made that it was difficult for all those interested in the study to grasp clearly just what had been done and what remained to be done. Questions were raised about points already settled, and a certain amount of confusion seemed to exist.

To give everyone concerned a common understanding and to furnish a fresh starting point for further study, the progress chart,

PROGRESS CHART				9187 COVER
No.	Operation	Old time allowed	New time allowed	Remarks
0-1	Blank and draw	0.0025	0.0011	Set-up improved-method of feeding changed-air ejector added
0-2	Separate scrap	—	0.0005	Operation added due to combination of 0-1 and 0-3
0-3	Trim	0.0025	—	Eliminated-combined with 0-1
0-4	Perforate	0.0050	0.0015	New die eliminates slugs
0-5	Bead and curl	0.0034	0.0015	New die and mechanical ejection provided
0-6	Roll thread	0.0025		Set up to be improved to permit new method of feeding and drop delivery. Estimated new time 0.0014
0-7	Inspection	D.W.		Mechanical means of revolving part under consideration
				Boxes designed for better material handling

FIG. 107.—Progress process chart in tabulated form.

Fig. 106, was prepared. By comparing it with the operation process chart, Fig. 31, it will be seen that the chart is the same with the exception of the heading and the notes added to show what the status of each operation is.

This form of progress chart has certain definite advantages. It is in the same form as the operation process chart previously prepared and hence can be readily interpreted by anyone who is familiar with the operation chart. Further, it shows the operations in order and in their relation to one another; since the suggested changes on one operation often affect other operations, this is highly desirable.

The other form of progress chart in tabulated form is shown by Fig. 107. This chart covers the stamping for which the flow

chart, Fig. 36 of Chap. VIII, was prepared. The tabulated form of progress chart possesses the advantage of being easy to prepare, since the whole chart may be made on a typewriter. If the job that it covers is fairly simple, this form is entirely satisfactory.

Uses of Progress Process Charts.—The use of the progress chart in connection with methods studies made by a group has already been pointed out. When the job is at all complicated and a number of different changes are contemplated, it will prove desirable to prepare an up-to-the-minute progress chart immediately before each meeting. If each group member has this chart before him, it will inform him of what has been accomplished on those phases of the study with which he himself is not connected and will prevent much unnecessary discussion and comment. Free discussion should, of course, be encouraged at all meetings, but it should be discussion that will develop new ideas rather than a review of what has gone before.

The individual analyst will also find the progress chart a useful tool. It is seldom that a methods study can be started and carried through to a conclusion without interruption. Sometimes the methods study of a job must be carried on in conjunction with regular, routine rate-setting work. Again, because progress is often halted while information or a decision is being awaited, methods studies of several jobs may be conducted at the same time. In any case, it will prove helpful from time to time to construct a progress chart to show how the methods study stands and to make sure that future efforts will be directed effectively.

The analyst will in addition sometimes be questioned by his supervisor or other interested individuals concerning the accomplishments that are resulting from his studies. A progress chart will answer such questions clearly and will enable the analyst to show what he is doing.

Conclusion.—The purpose of this volume has been first to give a general description of the various techniques of methods engineering and their relation to one another and then to discuss in some detail the procedures employed in connection with the first and a very important step of methods study, namely, operation analysis.

It will be seen that operation analysis is an entirely practical subject. The analyst, far from dealing with theoretical con-

siderations, seeks for practical result-getting improvements. The various tools that he uses—operation process charts, flow charts, the analysis sheet—are designed principally to guide his thinking and to keep clearly before him the points that he should study and seek to improve. The real accomplishments, however, are made by the analyst himself rather than by the tools that he uses. No chart or form will take the place of sound reasoning and constructive thinking.

The examples given of improvements that resulted from operation analysis were taken from a number of different industries. Many kinds of operations performed on many kinds of products were described. It is impossible, of course, to include all operations encountered in industry, but it is hoped that enough have been given to show once and for all the baselessness of the "our-work-is-different" attitude mentioned in Chap. III.

To the analyst, all work is much the same. The externals are different, of course, for every job studied, but there are many fundamental points of similarity. In most cases, a part is picked up, worked upon, and set down. Certain motions are employed that are common to all jobs. If they can be improved on one job, they can be improved on many jobs.

Analysis work is not limited to methods engineers but may be conducted by anyone who is interested in bringing about job improvement. If the analysis work is done systematically in accordance with the procedure described in this book, more will be accomplished than if the work is done haphazardly. Anyone connected with industry can apply the procedure outlined, for there is nothing particularly difficult or technical about it. The trained observer with a background of previous experience in making improvements will undoubtedly accomplish more than the man making his first analysis, for he will be able to recognize many possibilities for improvement at first glance and will know the action to take that will be most effective in getting the improvements made. The beginner should not be discouraged by this, however, for he too will accomplish more as he becomes more experienced, and the only way experience can be gained is by making a number of analyses.

A group consisting of a superintendent, design engineer, foreman, inspector, group leader, and perhaps others, led by an experienced methods engineer, when formed for the purpose of

studying a job in which all are interested, will accomplish much. Each member will approach the problem from his viewpoint, and if the viewpoints are coordinated by capable leadership, the results are likely to be much greater than an individual working alone can secure.

A methods study properly made consumes time and effort. Most industrial supervisors are so loaded with responsibilities and duties that they may find it difficult to give time to operation analysis. Nevertheless, the time should be found and used for that purpose. Progress is essential if an industry is to maintain its competitive position. Therefore, the type of analysis work that leads to improvement and progress is also essential. Just getting work out in accordance with an established routine is not sufficient. To advance, the work must be put out better today than it was yesterday and better still tomorrow.

Any industrial executive or supervisor who has the interests of his company at heart should, therefore, devote a portion of his time to analyzing the work that comes under his supervision and to improving it. Current problems are important, but at least 5 to 10 per cent of a week's time should be set aside for seeking improvements. If each supervisor of an organization will do this and will conscientiously do his best to make changes that will reduce waste and increase productive effectiveness, the organization will soon attain an enviable position.

Management has a certain responsibility in this connection. It should encourage the search for improvements; it should consider all suggestions made, adopting as many as seem practical; and, finally, it should reward outstanding accomplishments as an incentive to further effort.

It should be remembered that any job can be improved if sufficient study is given it. This is literally true. There may be jobs here and there that cannot be improved further, but the authors have rarely encountered them. If they exist, they may be considered to be the exceptions that prove the rule. Throughout industry there are countless opportunities for improvement. Every operation in every plant offers a challenge. It can be done better. The problem is to find out how. Operation analysis is a method of finding out.

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